STRENGTH, FLEXIBILITY, FUNCTIONAL MOVEMENT, AND INJURY IN COLLEGIATE MEN FOOTBALL PLAYERS

by

DENNIS REX BRADBERRY

(Under the Direction of Michael Horvat)

ABSTRACT

The research for this dissertation investigated the relationship between functional movement screen scores, musculoskeletal injury, and strength/power in collegiate football athletes across the competitive season. Two studies were completed. In each study, participant's functional movement was assessed. In study 1, FMS scores and significant injury (defined as 10 or more days out) data were collected for the 2009 competitive season for one collegiate football team (n=67). A score of 11 on the FMS was found to yield acceptable specificity of 0.80 and sensitivity of 0.290. The odds ratio was found to be 9.778. The odds ratio can be interpreted as a player having a nine-fold increases chance of a significant injury when their FMS score is 11 or less when compared to a player whose score was greater than 11 at the start of the season. Study 2 investigated the relationship between the functional movement screen scores and strength/power in college football players. It was intended to study the relationship between functional movement and strength/power in collegiate football players in order to determine the correlation between these modifiable risk factors. The relationship between the FMS scores and strength/power was examined with all 97 players that participated during 2009-2010. The relationship between FMS and strength/power was investigated as two continuous variables.

SPSS 17.0 was used to run a significant test for the correlations. At the .01 level, there was a significant negative correlation between FMS composite score and bench press ($r = -0.299$) $p=.003$. At the .01 level, there was a significant negative correlation between FMS composite score and back squat ($r = -0.261$) $p=.010$. At the 0.01 level, there was not a significant correlation between FMS composite score and power clean ($r = -0.156$) $p=.124$. The functional movement screen was found to show some potential as an identifier in predicting significant injuries (as defined in this investigation) of 10 or more days out. Athletes with a lower FMS score were found to be more likely to sustain a significant injury if they scored 11 or less. The FMS was designed as a screening test to determine deficiencies and imbalances in movements not strength or power output. In spite of imbalances, the athlete can still genreate an adequate amount of strength/power to perform the standard football lifts. The results of this investigation lead us to believe that the muscle function can be strengthened to produce force even though functional flexibility may be compromised by asymmetries and imbalances.

Key Words: functional movement screen, strength, power, injury, college football

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DEDICATION

I dedicate this work to my family, friends, and professors who have supported me thorough my educational journey. Thanks for helping me continue to see the big picture and encouraging me to pursue my dreams. Mom and Dad, none of this would have been possible without you. I did it. PHIL 4:13

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CHAPTER 1

INTRODUCTION

Participants in athletic endeavors traditionally begin to experience injuries that precipitate loss of practice time during preliminary practice and during the competitive season. At the start of the season that includes preseason practice, drills, and scrimmages, several factors contribute to injuries including the conditioning of athletes, length and intensity of practice, and quality of equipment. Likewise the demands of competition also precipitate an injury that affect the health of participants and team success. Injury is defined as an act that damages or hurts (1). For athletic teams whose rosters and game plans are based on the health of their participants, remaining healthy is important.

The sport of football continues to be one of the most popular sports in the United States and is the largest contributor to sport-related injuries with approximately 500,000 injuries occurring per year in high school and college (7). With the advances in protective equipment, training regimens, and sports medicine, injuries still occur without any concrete evidence concerning causes or prevention.

The first step in possible prevention or decreases in injury, it is essential to evaluate all components of functioning which may facilitate an injury. Football requires athletes of various sizes, abilities, and functional performance levels who perform various techniques and skills on the field. Football is also a collision sport that is performed at a high rate of speed on venues with different surfaces. Injuries may occur in practice or game settings as well as preseason, in season, and offseason conditioning. Within the broad spectrum of injury prevention, it is essential to identify potential risk factors that may precipitate an injury. Initial efforts have addressed modifiable risk factors for injury in high school and college football such as previous injury, body mass index, and body composition (8). From this research it was found that previous ankle injuries significantly increased repeated ankle injuries; a higher body mass index increased the likelihood of injury. From these factors, it was evident that having a previous ankle sprain and being overweight (based on BMI and body composition) dramatically increased the risk of sustaining an ankle injury. In this isolated example, it appears that several factors can contribute injury. More importantly the ability to define and understand specific injury risk factors may provide vital information to trainers and coaches that could be incorporated to decrease or prevent specific injury. Recently an investigation on NFL players using the Functional Movement Screen indicated that a score of 14 or less was positive to predict serious injury and players who had scores of 14 or less were 11 times more likely to acquire a serious injury (6). It is our intention to extend this work to collegiate football players and investigate the relationship between the functional movement and strength/power. In order to determine modifiable risk factors and the extent of injuries, an accurate assessment device is required in the identification process that is specific to the sport and mechanics of movement. A recent device, the FMS, has been initially used with NFL players and shows some promise as a screening instrument.

Statement of the Problem

A preliminary investigation utilizing the FMS has indicated that National Football League (NFL) players with composite scores of < 14 on the Functional Movement Screen are more likely to be injured over the course of a season. This investigation found that NFL players with a score of 14 or less on the FMS were 11 times more likely to acquire a serious injury (6). With any new assessment, specific research applications are lacking and to our knowledge no studies have been conducted with college football players. In contrast, research on strength measures such as the bench press, back squat, and power clean and the effect on performance can be found although their relation to function has not been determined. At this time the relationship of injury to functional movements and muscular strength/power in collegiate football has not been determined. Therefore, the primary purpose of this study is to determine if the Functional Movement Screen (FMS) can be used as a predictor of injury in college football players. Another purpose is to determine the relationship between the FMS and muscular strength/power.

Specific Aim

To determine the relationship between the functional movement scores, strength/power, and injury rates across the competitive season of collegiate football players.

Hypothesis

The following hypothesis was tested at the .05 significance level. 1. There will be a significant relationship between FMS scores and injury rate in college football players. 2. There will be a significant relationship between the FMS and strength/power. A college football player with a lower functional movement score who possesses strength will have a higher likelihood for injury during the competitive season.

Significance of the Study

The intent of this study is to identify risk factors for injury in college football players over the duration of a competitive season. This study will be the first to explore the relationship between these risk factors, strength/power, and injury rates.

In the sport of football injury prevention is a primary component of a training program in addition to improving a player's strength, flexibility, power, and overall performance. The ability to identify potential weaknesses in player's functional capacity can provide the strength and conditioning professional with the capabilities to strengthen compromised areas as well as improving movement patterns and performance that possibly reduce injury. If deficient areas are not corrected, faulty mechanics made by the body that result from compensations produce inefficient movements which ultimately decrease power output and performance. Previous research has indicated that having lower power output and inefficient movement patterns can potentially lead to an increase in injury and provide rationale for this investigation. If a relationship can be established between college football players functional movement score, strength/power, and injury across the competitive season, specific training and prehabilitaton programs can be more effectively designed to overcome these deficiencies.

Limitations of the Study

The following are limitations of the study:

1. The findings of this study are comparable only to other studies utilizing the Functional Movement Screen and its relationship to injury.

2. The findings of this study are comparable only to other studies utilizing college football players across the competitive season.

3. The finding from this study will only be comparable to other studies utilizing the specific equipment and methods used in this study.

Delimitations of the Study

This study is delimited to 85 college football players (ages 18-23 years) at a Division I university. These college football players were enrolled in classes at the university and participated in the 2009 – 2010 season.

Definition of Terms

The following terms are defined in this investigation based on two categories, conceptual definitions and functional definitions. Conceptual definitions are concepts that have been defined by recognized sources. Functional definitions are ones that are utilized for this particular investigation.

Conceptual Definitions

Movement- included any change in the position of your body parts relative to each other (5).

Physical Activity-intentional, voluntary movement directed toward achieving an identifiable goal (5).

Strength- the maximal force that a muscle or muscle group can generate at a specific velocity (2).

Injury - is an act that damages or hurts. A hurt, damage, or loss sustained (1).

Macrotrauma-is a specific, sudden episode of over-load injury to a given tissue, resulting in disrupted tissue integrity (2).

Microtrauma-overuse injury, results from repeated, abnormal stress applied to a tissue by continuous training or training with too little recovery time (2).

Functional Definitions

Power - is a function of force and velocity (P = F x D/T), making fast motor units the main contributors to powerful movements (3).

Functional Movement Screen - The Functional Movement Screen (FMS) is a system used to evaluate movement pattern quality. The test is comprised of seven fundamental movement patterns that require a balance of mobility and stability (9).

Predictor variable – the variable(s) from which projections are made in a prediction study (4).

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CHAPTER 2

REVIEW OF LITERATURE

This chapter presents a review of the literature related to this study of the relationship between college football players functional movement score, strength/power, and injury across the competitive season. This chapter outlines research findings under the following categories: (a) a brief history of football, (b) flexibility, strength/power and injury and how they relate with football, (c) functional movement screen and score, (d) standard football lifts: bench press, back squat, power clean and (e) summary of the literature review.

A Brief History of Football

Football is a sport that is played by all ages across the entire United States. The sport of football has been popular in the United States for over 100 years. The first intercollegiate football game was played in 1869 between the Rutgers and Princeton. Professional football emerged on the scene in 1892. As the game became more organized and professional, the National Football League (NFL) was formed in 1920. Since its beginnings in 1869, football has now emerged as a multi-billion dollar sport. It is an important source of revenue for television networks, owners, and cities. Several games are aired every weekend during the football season and the NFL has become the most popular viewed sports league in the United States (6). As the sport of football has become more and more popular, participation has increased across the years. During 1981-1982, there were 497 teams across all divisions in college football with a total of 40,733 athletes. Both of these numbers increased as there were 522 teams with 47,942 athletes in 1988-1989 (26). The growing trend continued across the next decade. The NCAA reported that during the 1990-1991 seasons there were 534 teams with a total of 49,663 athletes across all divisions. Both of these participation rates continued to grow as there were 605 teams with

56,541 athletes by 1998-1999. By the year 2006-2007, the NCAA recorded a total of 625 teams with 62,459 athletes across all divisions in college football. This is 108 more teams with 15,808 more athletes since 1981-1982. This popularity and participation increase is also found among high school. The National Federation of State High School Associations conducted a summary and found that in 2006-2007, 11-player football once again topped the list of participation with 1,108,286 athletes. It is estimated that more than a million male high school athletes have participated in football in each of the past 4 years (18). This information leads us to believe that as the years continue to pass, the participation of the sport of football will continue to grow across all levels of play.

The fact that football is a multi-billion dollar sport provides support that its revenue is a major component of the US economy. This money is used for facilities, salaries, and revenue for media relations. The expenditures in 1998 for commercial sports, which included football, totaled $17.7 billion dollars (24). Forty six major league stadiums and arenas were built for teams in the four principal professional U.S. sports leagues, including the NFL, between 1990 and 1998. As of the end of 1999, an additional 49 professional sports facilities were either under construction or in the planning stages (3). More than 21.7 billion will be spent on these 95 stadiums and arenas built or planned since 1990. The average cost of facility construction in current dollars rose from $3.8 million in the 1950s, to $25 million in the 1960s, $71 million in the 1970s, $103 million in the 1980s and to $200 million from 1990 through 1998 (20). With its popularity increasing and as the years pass, more and more money is being invested into football.

This increase of money is also found in the salaries of football coaches. A USA TODAY study found that 42 of the 119 Division I-A coaches earned $1 million or more in 2006 which was up from 5 of the 119 in 1999. In 2009, the top 8 salaries in NCAA football exceed $3 million dollars. This is a large amount of money when it is considered that this just compensates the head coach, not all of his assistants and support staff. The fact that salaries of coaches continue to increase prove that there is positive revenue in the sport of football.

Media is also sharing in the growth of revenue in football. It is now generally acknowledged that mediated sports are a highly profitable commodity. The increased importance of media in sports is revealed in the scale of finances involved (24). In 1998, the cost for a 30-second spot for the Super Bowl averaged $1.6 million, which was up from $1.3 million in 1996. By 1999, the average price increased another 25% with one advertiser paying $3 million for a 30-second ad (15). College football also reaps the benefits of the sport being so popular with the media. A USA TODAY study reported that Auburn University signed a $51.3 million multimedia and marketing rights deal with ISP Sports beginning in 2008. While the deal will cover all Auburn sports teams, the athletic director says that its value is connected largely to fan and advertiser interest in football.

An issue that affects football directly, which could potentially affect revenue, is injuries. Since football began, injuries have affected the sport from rule changes, to teams losing their best players and potentially costing them a winning season. Football is a leading cause of sport-related injuries with an injury rate almost twice that of basketball, the second most popular sport (18). Injury rate in the sport of football is very complex. This complexity is due to the diversity of the human body, contact in the game, and strength/power that is required to compete. Research concludes that lower extremity injuries are more common than upper extremity injuries but both are complex issues. A contributing factor to this trend could be the mechanisms of injury. A study was conducted on the extensive comparison of injury mechanisms between high school and NCAA football players. In high school competition, contact with another player contributed to 77.1% of the injuries while contact with the field only contributed to 13.7% of the injuries. In the NCAA, contact with another player contributed to 74.5% of the injuries while contact with the field contributed only 7.5%. The specific mechanism that caused injury in high school competition listed tackling as 25.7%, being tackled as 33.5%, blocking as 24.7%, and stepped on/fallen on as 7.6%. For the NCAA, tackling in competition caused 26.9% of injuries, being tackled caused 28.6% of injuries, blocking caused 24.7% of injuries, and stepped on/fallen on caused 8.7% of injuries (18). As the above statistical data supports, injury in football should be concern across all levels of play. It is important for coaches, trainers, and staff to gain knowledge about injury rate in order to attempt to deter it. If modifiable factors are identified in injury prevention for football, there could be potential to deter injury thus helping to contribute to the popularity of the sport.

Flexibility, Strength/Power, and Injury and its relation to Football

The game of football has evolved over the years with the advances in training, equipment, and sports medicine, but one thing has remained constant, injuries. Football is a sport that requires athletes of all sizes and strengths to perform different tasks. Since football is a collisions sport with such a variety of athletes, injury rate remains prevalent. Strength and Conditioning coaches, athletic trainers, and medical staffs are constantly working together to deter and prevent injuries. Literature reveals that flexibility and strength are two major components that are researched when injury prevention is being addressed. Coaches, trainers, and medical staffs agree that the more strength and flexibility and athlete acquires, the better chance of injury prevention.

Flexibility is defined as the available range of motion at a given joint. In a study looking at the relationship between range of motion and muscle strains, it was found that athletes sustaining a muscle strain injury in the hip flexors or knee flexors had lower preseason range of motion ($p<.05$) in these muscle groups compared with uninjured players. This study continued to find similar trends in the remaining muscle groups (8). Twenty-seven studies conducted since 1962 have shown that stretching effectively increases muscle flexibility and joint range of motion. An athlete who engages in a consistent flexibility training program can experience improvements in flexibility that last for several weeks. While flexibility is an important contributor to performance in many sports, an athlete with a reduced range of motion may be subject to a greater risk of injury (17). In another study looking at flexibility and injury, it was discovered that a statistically significant difference was found between the injured and the uninjured players in quadriceps and hamstring muscle flexibility. For both muscles, the injured group showed a significantly lower mean flexibility. The data in this study showed a significant association between preseason hamstring muscle tightness and subsequent development of a hamstring muscle injury. A similar relationship was found for quadriceps (25). The fact that lower flexibility could potentially lead to injury is also supported by a review of eight studies that investigate the relationship between flexibility and injury of the hip adductors (11). In this study, it was found that flexibility is a parameter that may influence injury risk and that low adductor flexibility has been identified as a risk factor for injury in athletes (11).

Strength is defined as the quality of state of being strong. It is the capacity for exertion or endurance and the power to resist force (4). For over 20 years, strength and conditioning has been examined in an attempt to reduce the incidence of injury in sport. In 1984, a study was found in the National Strength and Conditioning Association journal that investigated conditioning and injury prevention in semi-professional football. In this journal entry, it was found that the Acworth Chargers of the Georgia Football League went through a pre-season conditioning and injury-prevention program. It was stated that the athletes went through this program in an attempt to materially reduce injuries and improve athletic performance (19). Literature continues to state that it is up to the coach and trainer to devise means of training which are effective in avoiding injuries (1). It also suggests that strength training can be such a means as it develops muscle, tendon and ligament strength, and develops structural balance (1). Literature also suggests that when developing strength for an athlete, it is important to keep in mind the sports most popular injuries (1).

In one particular study, progressive resistance training was found to be a basis of year round training programs for many sports. Training effects including muscle fiber hypertrophy, improved muscle fiber recruitment, increased strength of tendons and ligaments, and increased bone density are often equated with improved resistance to physical injury on the playing field (14). Literature supports that adequate strength throughout the body is effective in potentially preventing injury. One study suggests that adaptation caused from strength training programs have led sport medicine professionals to equate them with improved resistance to injury. This study continues to state that it is widely assumed that muscles with greater strength and joints with greater integrity are less susceptible to injuries (14). This is supported by a study conducted by Tyler and colleagues investigating strength and injury. Even though the investigators admitted that their findings needed to be duplicated in larger studies involving other sports for the results to be universally accepted, they concluded that addressing adductor strength deficits reduced injury risk in professional ice hockey athletes (21).

Functional Movement Screen and Score

The Functional Movement Screen is a 7 point screen that assesses basic movement patterns. It was designed to identify an athlete's limitations along with imbalances. The screen requires muscular strength, flexibility, and stability while the body moves through a variety of ranges of motion. It has been observed that the athlete's body's ability to move through fundamental movement patterns is not assessed in most cases. The FMS provides a 7-point screen to assess the athlete's total body along with basic movement patterns. The 7 basic movement patterns that are observed are as follows: 1) Deep Squat 2) Hurdle Step 3) In-Line Lunge 4) Shoulder Mobility 5) Active Straight Leg Raise 6) Trunk Stability Push Up 7) Rotary Stability. An individual is provided with three attempts to perform each of the 7 movement patterns. The best of the three attempts is scored. The scores for the Functional Movement Screen range from zero to three. The best a total composite score can be is 21.

One of the primary benefits of flexibility in the sport of football is the potential for injury prevention. It is assumed that assessing multiple domains of function (balance, strength, and range of motion) simultaneously may potentially improve the accuracy of identifying athletes at risk for injury. Because football is a sport that often places athletes in multiple domains of function, functional flexibility is a necessity for injury prevention. The Functional Movement Screen provides a way to assess functional flexibility. In one particular study conducted with professional football players, the relationship between an athlete's Functional Movement Score and the likelihood of a serious injury was examined (13). The researchers found that the mean score for all athletes tested was 16.9. The mean score for those who suffered an injury was 14.3 and 17.4 for those who were not injured. Upon analysis, it was determined that a Functional Movement Score of 14 maximized specificity and sensitivity of the test. The researchers continued to find an odds ratio of 11.67. This value was interpreted as an athlete having an eleven fold increased chance of injury when their Functional Movement Score was 14 or less when compared to a player whose score was greater than 14 at the start of the season (13). In another study, the Functional Movement Screen was performed on 433 firefighters in order to analyze the correlation between the Functional Movement Score and injuries. It was also conducted to evaluate a training program designed from Functional Movement Scores to improve flexibility and strength in core muscle groups. The researchers found that the Functional Movement Screen provided information for the intervention program that reduced lost time due to injuries by 62% and the number of total injuries by 42% over a 12 month period. They concluded that these finding warranted both core strength and functional movement enhancement programs in order to prevent injuries (16).

In sport of football, it is important to attempt to improve each athlete's strength, flexibility, power, and function along with preventing injury. It is important for each athlete to identify personal weaknesses and work to improve each of them. These improvements will not only increase movement and performance, but can also positively affect team performance. The Functional Movement Screen provides a quick and efficient way to assess basic movement patterns in order to identify weaknesses. Once the weaknesses are identified, individual programs can be designed to correct and improve them. It is essential to assess an athlete's basic movement patterns prior to beginning a training program. This will assist the coach or specialists in identifying weak areas in function and movement. If the weak areas are not corrected, the body will compensate with inefficient movements which can lead to a decrease in performance and potentially an increase in injury. The Functional Movement Screen attempts to identify these weaknesses by requiring the body to move through a variety of movement patterns and then provides exercises to correct them. If corrections can be accomplished, hopefully performance will increase and injury rate will decrease.

Standard Football Lifts: Bench Press, Back Squat, Power Clean

Conditioning in the sport football is a vital component in each individual program. The conditioning program is responsible for developing team strength, power, and speed along with building each athlete's body to resist injury. Three lifts that are commonly associated with conditioning in football are the bench press, back squat, and power clean. In addition, the bench press and squat are two of the most often used core exercises in resistance training programs for college football players (23). Literature states that strengthening and increasing the mass of the shoulder girdle can help prevent upper quadrant injuries and exercises such as the bench press are great exercises to meet these goals (10). Another study which proves the importance of conditioning supports that the bench and squat are both good exercises to build general strength capabilities. The sport of football requires all athletes to develop a good strength level in both the upper and lower body and both of these exercises are beneficial in obtaining these goals (5). In a study investigating the effect of the back squat on power production, it was found that the squat combined with plyometrics can significantly increase power movements that are performed by athletes (2). Since power is a necessity in football, squats will continue to be used in conditioning programs. The power clean is an exercise that is used to develop power throughout the body. Literature suggests that the clean is a great measure of lower-body power and overall athleticism (5). Football is a sport that will continue to demand great levels of strength and power as long as it is played. The literature supports a conditioning program using the bench press, back squat, and power clean to develop strength and power in athletes participating in football.

Summary

As the literature supports, football is a sport that is on constant rise in both popularity and participation. An overview of the history provides evidence that football is one of the more popular sports and will continue to grow with is revenue. Injury rate may potentially affect the participation rate of football and therefore is an important factor to investigate. The review of the literature provide some evidence that a relationship exists between flexibility, strength, and injury but there is a need for a better understanding of this relationship, specifically with the sport of football. The functional movement screen has been shown to potentially be a predictor of injury in professional football and the information it provides could contribute with this understanding. The power index value encompasses the three main lifts that test total body strength in football athletes and can be used with the functional movement screen to establish a relationship with injury. If these modifiable factors can be clearly identified in their relationship to injury, a potential to deter injury would be a possibility, thus helping to contribute to the growth of the sport.

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CHAPTER 3

THE RELATIONSHIP OF THE FUNCTIONAL MOVEMENT SCREENING TEST AND INJURY IN COLLEGIATE FOOTBALL

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Abstract

Introduction/Purpose: This study investigated the relationship between the functional movement screen scores and musculoskeletal injury in collegiate football athletes across the competitive season. **Methods:** FMS scores and significant injury (defined as 10 or more days out and did not include concussions or bone injuries) data were collected for the 2009 competitive season for one collegiate football team (n=67). FMS scores were collected at the end of summer conditioning, prior to the start of fall camp. Injuries were recorded throughout the season. A receiver operator curve was used to optimally dichotomize the FMS score with respect to predicting significant injuries. **Results:** A score of 11 on the FMS was found to yield acceptable specificity of 0.80 and sensitivity of 0.290. The mean (SD) FMS score for all players (n=67) was 12.54 (2.338). The mean (SD) FMS score for players (n=62) who did not have significant injuries of 10 or more days was 12.66 (.297). The mean (SD) FMS score for players who had a significant injury of 10 or more days out was 11.00 (.837). The odds ratio was found to be 9.778. The odds ratio can be interpreted as a player having a nine-fold increase in his odds of sustaining a significant injury when his FMS score is 11 or less when compared to a player whose score was greater than 11 at the start of the season. **Discussion and Conclusion:** The results of this study indicate that the Functional Movement Screening test is an indicator of potential injuries in collegiate football players. It is also apparent that collegiate football players with poor fundamental patterns assessed with the FMS are more likely to suffer an injury than players who score higher on the test.

Key Words functional movement screen, injury, collegiate football

Introduction

Football is one of the largest contributors to sport-related injuries with an injury rate of over 500,000 injuries occurring per year in high school and collegiate football (3). This rate is almost twice that of basketball, the second most popular sport in the United States (3). Injuries continue to occur in spite of advances in protective equipment, training regimens, and sports medicine.

In order to prevent or decrease injuries, it is essential to evaluate all components of functioning which may facilitate an injury. Football requires athletes of various sizes, abilities, and functional performance levels who perform various techniques and skills on the field. Football is also a collision sport that is performed at a high rate of speed on venues with different surfaces. Injuries may occur in practice or game settings as well as preseason, in season, and offseason conditioning. A critical component of injury prevention is the compilation of data to identify potential risk factors for injury in collegiate football players. Recent efforts have addressed some modifiable risk factors for injury in high school and college football such as previous injury, body mass index, and body composition (4). For example, Tyler and colleagues discovered that ankle injury incidence was significantly higher in athletes with previous ankle injuries and that athletes with a high body mass index were more likely to have an injury than an athlete with normal body mass index indicating a previous ankle sprain and being overweight (based on BMI) dramatically increased the risk (4). In this context, it is essential to define and understand specific risk factors that may provide vital information from multidimensional factors for trainers and coaches that can be incorporated to decrease the potential for injury.

Since football is a leading cause of sports-related injuries, this study was designed to apply the functional movement screening test (FMS) developed by Cook and Burton to collegiate football athletes. In order to determine the extent of injuries, an accurate assessment device is required to identify possible risk factors as well as be specific to the sport and mechanics of movement. The FMS has been used to detect injuries with professional players (1) and shows some promise as a screening instrument that could be applied to collegiate players. Although some research is available on football related injuries, it is important to determine if any components can be modified to eliminate or decrease injury. Based on previous research with the Functional Movement Screen, the FMS assesses fundamental movement patterns that identify limitations or asymmetries in an athlete's function (1). An earlier study applied the FMS to NFL players and it was reported that professional football players with composite scores of <14 on the Functional Movement Screen are more likely to be injured over the course of a competitive season (1). Since the FMS is a relatively new assessment, little information on its usage is available and to our knowledge no studies have been conducted with college football players. This absence of information on the relationship of injury to functional movements is critical for trainers and/or coaches to identify potential problem areas that could possibly be modified with training interventions. Therefore, the primary purpose of this study is to determine if the Functional Movement Screen can be used to predict injury in college football players. This study is also being conducted to determine the relationship between functional movement scores and sport related injury rates across the competitive season. It is our intention to study the relationship between functional movement and injury in collegiate football athletes in order to determine if these modifiable risk factors can potentially decrease injury rate in collegiate football.

Methods

Experimental Approach to the Problem

In the sport of football, injury prevention is a primary component of a training program in addition to improving a player's strength, flexibility, power, and overall function. The ability to identify individual weaknesses in players may decrease injury rates as well as improve their movement patterns and overall performance. If deficient areas are not corrected, the body will compensate with inefficient movements which can lead to a decrease in power output and performance. The Functional Movement Screen (FMS) provides a quick and efficient way to assess basic movement patterns in order to identify individual weaknesses and limitations.gth and flexibility assessments. Once the weak and limited movement patterns are identified, individual programs can be designed to correct and/or improve potential area of weakness.

Previous research has indicated that having inefficient movement patterns in professional football players can potentially lead to an increase in injury rates (1) and provide the rationale to extend this investigation to collegiate players. The information provided by this study should be valuable to everyone who is involved in training and rehabilitation at any level of competition. If a relationship can be established between a college football player's functional movement score and injury rates across the competitive season, specific training and prehabilitaton programs can be designed to reduce the risk of injury by overcoming these deficiencies.

The subjects used for this study included players who had equal athletic exposures. An athletic exposure consisted of 1 athlete participating in 1 practice or game. A significant injury was defined as one that kept a player out of practice or competition for 10 or more consecutive days. For the purpose of this study, concussions and physical illness were not included as injuries.

Subjects

Collegiate football players from 18-23 years of age (N=67) that competed during the 2009-2010 season for a major Division I program participated in this study. The assessments were part of the annual screening of football participants at the University and were approved by the Director of Sports Medicine, the Director of Strength and Conditioning, and the Head Football Coach. The study was approved by the University of Georgia's Institutional Review Board.

Test Descriptions

The FMS was designed to assess components of mobility and stability and to determine if asymmetries and/or overall limitations are present in the athlete (5). Research on the FMS indicates that it has high interrater reliability and can confidently be applied by trained individuals when the standard procedure is used (2). The FMS requires the athlete to possess muscular strength, flexibility, and stability while the body moves through specific movements and ranges of motion (5). The FMS is designed to identify limitations along with right and left side imbalances with basic levels of movement. It is important to understand that these imbalances can distort motor learning, movement perception, body awareness and movement mechanics. Individuals learn to adapt their movement patterns with their imbalances and are not as efficient as they potentially could be if these imbalances were corrected. The purpose of the screening instrument is to identify potential limitations and imbalances in an individual's movement patterns. For example, if an athlete cannot achieve the perfect score on the deep squat, their movement patterns could be limited due to tightness in the shoulders and hips. The functional movement screen is designed to study fundamental movement patterns like the squat in an effort to determine limitations in movements as well as allows understanding of the interaction between mobility and stability and concomitant areas of weaknesses. The combination of poor mobility and stability is the source of many common problems, thus identifying these problems may help with preventing them.

Each participant is provided with three attempts to perform each of the 7 movement patterns. The best of the three attempts is scored. If a participant performs the movement perfectly on the first attempt, then the tester will move on to the next test. During a screen where bilateral movement is assessed, a score needs to be recorded for both the left and right sides of the body (see score sheet in appendix a). The lower of the two scores is counted toward the total. The scores for the FMS range from zero to three. A participant is given a score of zero if at any time they experience pain during the testing. The tester should stop that particular portion of the screen and move to the next test. A score of one is given if the participant is unable to complete the movement pattern or is unable to get into position to perform the movement. A score of two is given if the participant is able to complete the movement pattern but compensates in some way to fully complete the movement. A score of three is given if a participant performs the movement correctly without any compensation.

The FMS requires a minimal amount of equipment. A 2 x 6 board is used to perform the deep squat is a perfect score is not obtained. It is also used during the in-line lunge, active straight leg raise and rotary stability tests for reliability. A 5 foot dowel is used for the deep squat, in-line lunge, hurdle step and active straight leg raise. The dowel is used for reliability, improve scoring, and to make the test more functional. A hurdle is used for the hurdle step which allows for body relative testing and improved scoring. A tape measure is used to measure distances in the shoulder mobility and in-line lunge. All the equipment is provided in the 2 x 6 board and is designed to be very light and user-friendly. The FMS assesses basic movement patterns, imbalances, and individual limitations. In this context the FMS was designed to assess components of mobility and stability and to determine if asymmetries and/or overall limitations are present in the athlete. The FMS requires the athlete to possess muscular strength, flexibility, and stability while the body moves through specific movements and ranges of motion. This allows the tester to observe the body's ability to move through fundamental movement patterns through the entire body and uncover areas of weakness that may predispose the athlete to injury. The 7 basic movement patterns that are observed are as follows: 1) Deep Squat 2) Hurdle Step 3) In-Line Lunge 4) Shoulder Mobility 5) Active Straight Leg Raise 6) Trunk Stability Push Up 7) Rotary Stability. (See appendix a for example) By using these movements, the FMS is able to identify limitations in ranges of motion along with right and left side imbalances while performing a basic movement. Imbalances can predispose the athlete to injury and alter movement perception, body awareness, and movement mechanics. Altered mechanics cause individuals to adapt movement patterns to accommodate their imbalances and potentially are the underlying indicators of future injury if these imbalances are not corrected. According to the developers of the FMS, the instrument is designed identify limitations and imbalances in an individual's movement patterns that may be precursors to injuries (5). In this context it is appropriate to evaluate the adaptability of the instrument to accurately predict risk of injuries with weaknesses in the athlete and whether the FMS correlates with standard assessments commonly done in strength and conditioning and athletic training.

Procedures

Procedures used in this investigation are Functional Movement Screen assessments and injury recording. Following approval from the University of Georgia Institutional Review Board, the participant will complete the FMS. The FMS requires a certified tester and will be performed by certified athletic trainers at the University of Georgia during summer conditioning. Participants then followed normal in-season practice, training, and competition. Injury rates were recorded by the athletic training staff and coded according to type of injury and part of the body where the injury occurred as well as the length of time missed.

Research Design

The focus of this study is to determine the relationship of the FMS and significant injury rates in Division I collegiate football players. The operational definition for significant injury was one that kept the athlete out of participation for 10 or more days and the study was designed to investigate if FMS scores would likely indicate chances for significant injury. Each athlete went through FMS assessments that were administered by certified athletic trainers employed at the University of Georgia as part of the preseason screening for athletes during the summer and prior to the beginning of the season. Interater reliability was calculated by comparing scores by two testers and was recorded at .90. Injuries were documented by trainers during the in-season and coded on the type of injury, body part/extremity, location where the injury occurred and amount of time missed. This information was recorded by certified athletic trainers at the University of Georgia and was protected to ensure the participants confidentiality. The specific aim of this study was to determine if a relationship is apparent with the functional movement screen scores and injuries that may occur and may be amenable to training interventions.

Statistical Analysis

A t-test was used to determine if those participants who were injured have a statistically significantly different mean FMS score than those participants who were not injured. This study examined if the FMS score differs for injured and un-injured players by first doing a t-test using FMS as a continuous variable and then dichotomizing the FMS score and examining the effectiveness of the dichotomized FMS score as a variable to predict injury. In addition, significant differences were evaluated between composite FMS scores and significant injury at the .05 level of significance. Also, using the procedures from Kiesel and colleagues (1), the cut off score was created by creating a receiver operator characteristic (ROC) curve (See figure 3.1). Kiesel and colleagues (1) used the ROC curve to determine if a player was at risk for injury and to determine specific cut-off points to maximize sensitivity and specificity. Using this cut-point, participants were divided into groups with high and low FMS scores. This was performed to determine if the odds of being injured are different for participants who have high versus low FMS scores. Similar to Kiesel and colleagues (1), how much the FMS score influenced the probability of injury is quantified and is a primary focus of our study.

Results

Data was collected for 67 participants from a total pool of 85 players. If a player was injured at the time of testing, data was unable to be recorded and those players were not able to participate in this study. Of the 67 players for whom FMS scores were recorded, 5 sustained at least one significant injury, with a significant injury being defined as one that prohibits a player from participating for 10 or more consecutive days. Because of the operational definition of significant injury, minor injuries that limited practice time or competition under 10 days were not recorded. The mean (SD) FMS score for all players (n=67) was 12.54 (2.338). The mean (SD) FMS score for players (n=62) who were not injured was 12.66(.297) while the mean (SD) FMS score for players who were injured (n = 5) was 11.00 (0.837). A t-test revealed (df=65, t=1.545, p = 0.0635 (one-sided p-value)) which is not significant at 0.05 level but is significant at 0.10 level, with the one-sided p-value.

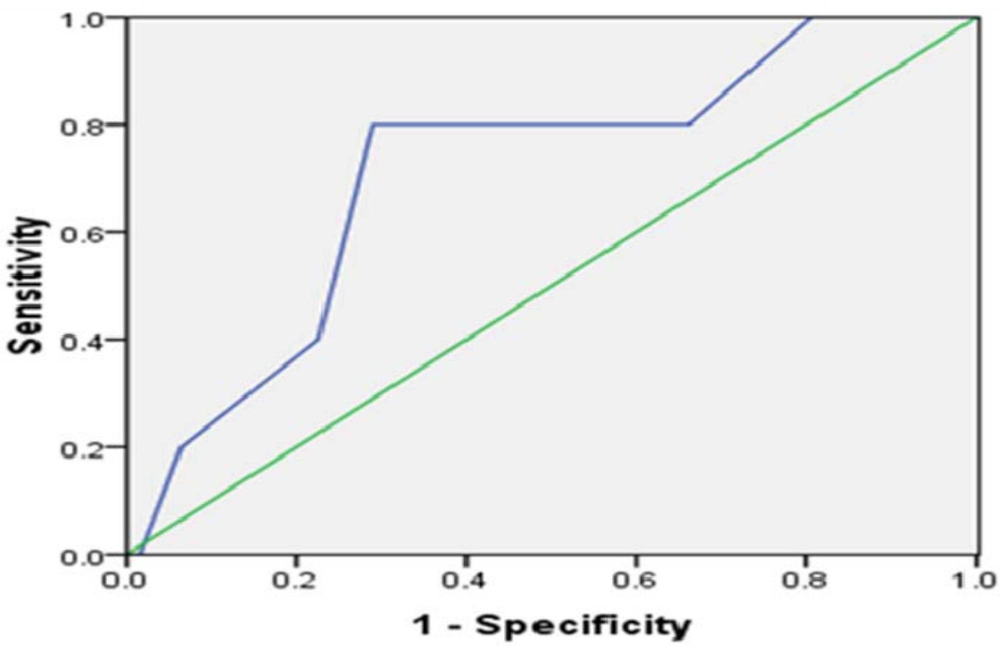

Figure 3.1 Receiver-operator score and injury status.

Positive if Less Than or Equal To[a]	Sensitivity	1 - Specificity
7.00	.000	.000
8.50	.000	.016
9.50	.200	.065
10.50	.400	.226
11.50	.800	.290
12.50	.800	.484
13.50	.800	.661
14.50	1.000	.806
15.50	1.000	.903
16.50	1.000	.952
17.50	1.000	.968
19.00	1.000	.984
21.00	1.000	1.000

Figure 3.2 Coordinates of the ROC curve showing that the FMS composite score value which corresponds best with the upper left hand portion of the curve is 11.50 justifying the cut-off score of 11.

An ROC curve was utilized to dichotomize the FMS score. Upon analysis of the ROC curve (see figure 3.1) and table of sensitivity and specificity values (as noted in Figure 3.2), it was determined that an FMS score of 11.5 maximized the specificity and sensitivity of the test. As highlighted in Figure 2, the cut-score yields acceptable values of sensitivity (.800) and specificity (.710). Since the cut-off score was 11.5 and the FMS score is always an integer, we divided the players into two groups: an FMS less than or equal to 11 and an FMS greater than or equal to 12. As noted in Figure 3.3, a 2 x 2 table was created by dichotomizing the FMS and Injury variables.

	Days Injured ≥ 10?	
FMS score ≤ 11?	YES	NO
YES	4	18
NO	1	44

Figure 3.3 2x2 Contingency table indicating if an athlete's FMS score was above or below the cut-off score and if they had suffered a significant injury.

Using the values in this table, it can be seen how the cut-off score results in sensitivity of 0.80 and a specificity of 0.71. The odds ratio was (4/22)/ (1-(4/22) / (1/45)/ (1- (1/45)) = 0.2222/0.0227 = 9.778. The confidence interval for the odds ratio was: $(e^{.579}, e^{3.98})$ = (1.78, 53.52). Since the 95% confidence interval does not contain 1, the true odds of getting a significant injury are different for the two groups (high and low FMS). The positive likelihood ratio value is the value associated with the FMS. The FMS is considered negative for a participant when his score is above the cut-off score determined by the ROC curve. The FMS is considered positive if a participant's score is equal to or below the cut-off score determined by the ROC curve. The positive likelihood ratio (LR+) = sensitivity/ (1-specificity) = 0.80/0.29 = 2.759. The negative likelihood ratio (LR-) = (1-sensitivity)/specificity = 0.20/0.29 = 0.690.

The odds ratio of 9.8 can be interpreted as a player having a nine-fold increased odds of injury when their FMS score is 11 or less when compared to a player whose score was greater than 11 at the start of the season. Our pre-test odds (using the value of 0.15 used by Kiesel and colleagues (1)) were found to be 0.15/0.85= 0.1764. We then multiply the pre-test odds by LR+ to get the post-test odds. This was found to be 0.1764*2.759 = 0.487. We continued to convert the post-test odds back to probability and found 0.487/1.487 = 0.327. So, if a player's score is 11 or less, their probability of suffering a significant injury increased from 15% to 32.7%.

In contrast, Kiesel and colleagues (1) found the cut off score for NFL players used in their study to be 14 while the odds ratio was 11.67. They concluded that a player that had a score of 14 or less at the start of the season had an eleven fold increased chance of injury. It was also apparent that the post test probability was found to be 0.51 which suggested that an NFL player who scored 14 or less on the FMS had an increased chance of suffering a severe injury that in fact increased from 15% (pre-test probability of 0.15) to 51% (post-test probability of 0.51). The higher FMS cutoff score may reflect the advanced conditioning and maturation of older athletes who may have had more time to physically adapt to training procedures. It also could suggest that collegiate players are not as physically mature as their NFL counterparts.

Discussion

The FMS has shown some potential as an identifier in predicting significant injuries of 10 or more days out. It was found that athletes with lower FMS scores are more likely to sustain a significant injury if they score 11 or less on the FMS. The cut off score of 11 suggests limitations in fundamental movement patterns, weaknesses, or asymmetries that increase the susceptibility to injury. For example, one athlete who scored below the cut off score suffered the same injury as another athlete who scored above the cut off score. The athlete who scored below the cut off score was “out” of practice and competition for more days than the athlete who scored above the cut off score. These findings suggest that the FMS demonstrates some promise in establishing commonalities or trends between lower scores and the rate of injury. However it does not establish a specific cause-effect relationship for injury. The score indicates a limitation that may predispose the athlete to injury or identify possible limitations that can be modified by the sports medicine or strength and conditioning staff. The value of determining these limitations is that they can possibly be used to correct a limitation or decrease the potential for injury. It is also possible that a player with a limitation may also avoid injury or miss a minimal amount of time under our operational definition of 10 days out. However if the FMS can be used to prevent any injuries, it would be helpful to the sports medicine and strength and conditioning personnel.

One limitation of our study was that our data analysis was only concluded from one team and was used for injuries that affected participation of 10 or more days. This operational definition of injury was selected to look at long term losses in time and participation and may not have captured all the meaningful injuries that commonly occur during the season and result in missing time or limitations in practice. However, it does provide some important information that may be helpful in determining limitations in athletes that can be overcome with specific training or strengthening procedures.

An important component from the study is providing basic information on injury research and prevention. The ability to access data from multi populations will allow researchers to establish more commonalities between FMS and injury and hopefully provide specific scoring ranges for all tests that can be used as a baseline for all athletes. Because of the nature of the sport, football injuries will continue to occur. However, if determining specific functional movement scores potentially some of these injuries may be avoided. This information could potentially educate athletic trainers, physical therapists, and strength and conditioning coaches and improve their off-season conditioning and rehabilitation programs. The FMS continues to gain acceptance as a screening device used by the NFL as well as the University of Georgia as part of all athlete's physicals.

Conclusion

The intent of this study is to identify modifiable risk factors for injury in college football players over the duration of a competitive season. This study was the first to explore the relationship between these modifiable risk factors and injury in this particular population. In the sport of football injury prevention is a primary component of a training program in addition to improving a player's strength, flexibility, power, and function. The ability to identify individual weaknesses in player's can decrease injury. The Functional Movement Screen provides a quick and efficient way to assess basic movement patterns in order to identify individual weaknesses. Once the weaknesses are identified, individual programs can be designed to correct and improve them. This study found that collegiate football players with a lower FMS score (less than 11) had a greater chance of suffering a severe injury over the course of the competitive season.

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CHAPTER 4

THE RELATIONSHIP OF THE FUNCTIONAL MOVEMENT SCREEN TEST AND STRENGTH/POWER IN COLLEGE FOOTBALL PLAYERS

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Abstract

Introduction/Purpose: This study investigated the relationship between the functional movement screen scores and strength/power in college football players. It was intended to study the relationship between functional movement and strength/power in collegiate football players in order to determine the correlation between these modifiable risk factors. **Methods:** Procedures used in this investigation are grouped into the following categories: (a) functional movement screen, and (b) a strength/power assessment. Each collegiate football player was put through a FMS using the deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push up, and rotary stability. Muscular strength was assessed to ascertain the athlete's strength/power, which was collected by each athlete's maximum weight lifted on the bench press, back squat, and power clean. **Results:** The relationship between the FMS scores and strength/power was examined with all 97 players that participated during 2009-2010. The relationship between FMS and strength/power was investigated as two continuous variables. SPSS 17.0 was used to run a significant test for the correlations. At the .01 level, there was a significant negative correlation between FMS composite score and bench press (r = -0.299) p=.003. The higher the FMS score, the lower the bench press max. At the .01 level, there was a significant negative correlation between FMS composite score and back squat (r = -0.261) p=.010. The higher the FMS score, the lower the back squat. At the 0.01 level, there was not a significant correlation between FMS composite score and power clean (r = -0.156) p=.124. **Discussion and Conclusion:** This investigation has shown that the higher the FMS score the lower the bench press, back squat, and power clean. These findings contradict convential wisdom that the tighter the muscle, the more strength and power the muscle may potentially posess for these three particular lifts. This is an important finding for strength coaches and

athletic trainers because a primary goal of any developmental program is to maximize each athletets potential while keeping them injury free. It is important for programs to avoid decreasing range of motion while developing strength/power.

Key Words functional movement screen, strength/power, college football

Introduction

Football is an extremely popular sport in the United States with more than a million male athletes participating in each of the past 4 years (9). Along with footballs popularity, development of physical functioning and improved performance continues to evolve with advances in sports medicine and strength and conditioning programs. Research supports that strength/power training has a positive effect on increasing performance. This was evident in a recent study that reported that athletes that performed higher in the hang power clean also had higher performances in sprinting, jumping, and changing of direction (7). Similar findings indicated that a back squat training program improved maximal leg strength and peak power output thus improving vertical jump performance and field performance in athletes (3). Likewise, Anderson and colleagues investigated both elastic and free weight resistance training that produced positive effects on strength and power (1). More importantly, defining and understanding specific training practices may provide vital information to trainers and coaches that could be incorporated in order to improve strength/power. In addition to the development of strength/power, football requires functional movements that are basic to the sport. With this in mind it was our intention to study the relationship between functional movement and strength/power in collegiate football athletes. To accomplish our goal, an assessment instrument (FMS) that is specific to the sport and mechanics of movement was used. This instrument has been used to measure functional movement with NFL players and shows some promise as a screening instrument (4). In addition, the NFL has included this device in the screening process for measuring injury risk and asymmetrical imbalances in functioning at the NFL scouting combine. Because of the scarce information available on the FMS and notably with collegiate football players, the purpose of this study is to determine if a relationship exist between the Functional Movement Screen score and strength/power in collegiate football players.

Methods

Experimental Approach to the Problem

To our knowledge, no current research has investigated the relationship between functional movement and strength/power. This project was designed to investigate the relationship between these variables in order to discover any relationships. While research on strength measures such as the bench press, back squat, and power clean and the effect on performance can be found, their relation to function as measured by the Functional Movement Screening test has not yet been determined. Therefore, the current investigation compares the bench press, back squat, and power clean with FMS. If a relationship can be established between college football player's functional movement score and strength/power across the competitive season, specific training and prehabilitaton programs can be more effectively designed.

Subjects

Collegiate football players from 18-23 years of age (N=97) that competed during the 2009-2010 season for a major Division I program participated in this study. The subjects were approved for participation in this investigation by the Director of Sports Medicine, Director of Strength and Conditioning, and Head Football Coach.

Study Design

The focus of this study is to investigate the relationship of the functional movement screening test and strength/power in Division I collegiate football players. If a relationship exists specific functional movement training could be incorporated into the strength and conditioning programs in order to help maximize athletic development.

Each collegiate football athlete was assessed with the FMS using the deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push up, and rotary stability. Muscular strength was assessed to ascertain the athlete's strength/power, which was collected by each athlete's maximum weight lifted on the bench press, back squat, and power clean. The primary aim of this study is to determine if a relationship is apparent with the functional movement screen test scores and strength/power.

Procedures

Procedures used in this investigation are grouped into the following categories: (a) functional movement screen, and (b) a strength/power assessment. Following approval from the University of Georgia Institutinal Review Board, the participant was assessed by a certified tester and certified athletic trainers at the University of Georgia. The Associate Head Strength and Conditioning Coach conducted the maximal lifts specific to each individual athlete that include the bench press, back squat, and power clean. Assessments were conducted at the end of summer workouts, which takes place during the last week of July. The researcher obtained this data from the athletic trainers and Associate Head Strength and Conditioning Coach once the testing procedure wascompleted.

Functional Movement Screen

The Functional Movement Screen is a 7 point screening test that assesses basic movement patterns. It's designed to measure individual's fundamental movement patterns and to provide observable performance of basic locomotor, manipulative, and stabilizing movements. The tests place the individual in extreme positions where weaknesses and imbalances become noticeable if appropriate stability and mobility is not utilized. Its design is to identify individual's limitations along with imbalances in an individual's movement patterns that may be precursors to injuries (10). The screen requires muscular strength, flexibility, and stability while the body moves through a variety of ranges of motion. (See score sheet and appendix a) It has been observed that the body's ability to move through fundamental movement patterns is not assessed in most cases and has not been compared to strength. The FMS provides a 7-point screen to assess the total body along with basic movement patterns. Each test is scored on an ordinal scale with 4 categories ranging from 0 to 3. A high score of 3 can be obtained in each of the 7 movement patterns thus producing a perfect score for the assessment of 21.

The FMS was designed to assess components of mobility and stability and to determine if asymmetries and/or overall limitations are present in the athlete. The FMS requires the athlete to possess muscular strength, flexibility, and stability while the body moves through specific movements and ranges of motion. The FMS is designed to identify limitations along with right and left side imbalances with basic levels of movement. It is important to understand that these imbalances can distort motor learning, movement perception, body awareness and movement mechanics. Individuals learn to adapt their movement patterns with their imbalances and are not as efficient as they potentially could be if these imbalances were corrected. The purpose of the screen is not to make a diagnosis, but to identify limitations and imbalances in an individual's movement patterns.

Each subject is provided with three attempts to perform each of the 7 movement patterns. The best of the three attempts is scored. If a subject performs the movement perfectly on the first attempt, then the tester will move on to the next test. During a screen where bilateral movement is assessed, a score needs to be recorded for both the left and right sides of the body (see score sheet in appendix a). The lower of the two scores is counted toward the total. The scores for the FMS range from zero to three. A subject is given a score of zero if at any time they experience pain during the testing. The tester should stop that particular portion of the screen and move to the next test. A score of one is given if the subject is unable to complete the movement pattern or is unable to get into position to perform the movement. A score of two is given if the subject is able to complete the movement pattern but compensates in some way to fully complete the movement. A score of three is given if a subject performs the movement correctly without any compensation (10). The intra-rater reliability of the FMS was analyzed using the weighted kappa statistic. The novice raters demonstrated excellence or substantial agreement on 14 of the 17 tests; whereas the expert raters did the same on 13 of 17 tests. When the novice raters were paired with the expert raters, all 17 components demonstrated excellent of substantial agreement (5).

The FMS utilizes a minimum amount of equipment. A 2 x 6 board is used for the deep squat as well as the in-line lunge, active straight leg raise and rotary stability tests. A 5 foot dowel is used for the deep squat, in-line lunge, hurdle step and active straight leg raise. A hurdle is used for the hurdle step and a tape measure is used to measure distances in the shoulder mobility and in-line lunge. The 7 basic movement patterns of the Functional Movement Screen that are observed are as follows: (see appendix a)

Deep Squat – The deep squat is used in the FMS to assess bilateral, symmetrical, and functional mobility of the hips, knees, and ankles. By holding the dowel overhead, the bilateral, symmetrical mobility of the shoulders and thoracic spine can be assessed. In order to perform the test, the subject must place his/her feet approximately shoulder with apart with the feet aligned in the sagittal plane. Next the subject places their hands on the dowel with approximately a 90-degree angle of the elbows with the dowel overhead. The dowel is then pressed overhead with the shoulders flexed and abducted, and the elbows extended. The subject is instructed to descend slowly into a squat position. The subject's heels should remain on the floor with his/her head and chest facing forward. During the test, the tester is looking to see if the upper torso is parallel with the tibia. The tester also should observe to see if the femur is below horizontal, the knees are aligned over the feet, and that the dowel is aligned over the feet. If these functional procedures are met, the subject would receive a perfect score of three.

Hurdle Step – The hurdle step is used in the FMS to challenge the body's proper stride mechanics. The hurdle step assesses bilateral functional mobility and stability of the hip, knees, and ankles during the stepping motion. The subject begins the test by placing the feet together and aligning the toes touching the base of the hurdle (2 x 6 board). The hurdle is adjusted to the height of the subject's tibial tuberosity. The dowel is placed across the shoulders below the neck. The subject steps over the hurdle and touches their heel to the floor while maintaining the stance leg in an extended position. The moving leg is then returned to the starting position. The subject is to perform the test with both legs. During the hurdle step, the tester is looking to make sure the subject maintains a stable torso and that their toes keep in contact with the hurdle during and after each repetition. The subject should never lock their knees and they should maintain proper alignment with the string and the tibial tuberosity. The hips, knees, and ankles should remain aligned in the sagittal plane and the dowel and hurdle should remain parallel. If these functional procedures are met, the subject would receive a perfect score of three.

In-Line Lunge – The in-line lunge is used in the FMS to place the body in a position that will focus on the stresses simulated during rotational, decelerating and lateral type movements. This test places the lower extremity in a scissor position, challenging the body's trunk and extremities to resist rotation and maintain proper alignment. It also assesses hip and ankle mobility, stability, quadriceps flexibility and knee stability. Before the subject can begin the test, the tester attains his/her tibia length. This is completed by measuring from the floor to the tibia tuberosity or acquiring it from the height of the string during the hurdle step. The subject places the end of their heel on the end of the board and the tibia measure is then applied from the end of the toes of the foot on the board and a mark is made. The dowel is places behind the back touching the head, thoracic spine and sacrum. The hand opposite the front foot should be grasping the dowel at the cervical spine and the other hand grasp the dowel at the lumbar spine. The subject steps out on the board placing the heel of the opposite foot at the indicated mark on the board. They begin to lower the back knee enough to touch the board behind the heel of the front foot and then return to the starting position. The subject is to perform the test with both legs. During the in-line lunge, the dowel is to remain in contact with the head, thoracic spine, and scrum. The front heel of the subject is to remain in contact with the board and the back heel touches board when the subject returns to the starting position. The tester is observing to see if there is no torso movement and that the dowel and feet remain in the sagittal plane. If these functional procedures are met, the subject would receive a perfect score of three.

Shoulder Mobility – The shoulder mobility screen is used in the FMS to assess bilateral shoulder range of motion. This test combines internal rotation with adduction and extension, and external rotation with abduction and flexion. Normal scapular mobility and thoracic spine extension is expected when performing this test. This is completed by determining the hand length by measuring the distance from the distal wrist crease to the tip of the third digit. The subject stands with feet together and remain in this position throughout the test. The subject is to make a fist with each hand with the thumb placed inside the fist. The subject is then asked to assume a maximally adducted, extended and internally rotated position with one shoulder, and a maximally abducted, flexed and externally rotated position with the other. The hands are to remain in a fist during the entire test and they are to be placed on the back in one smooth motion. The distance between the two closest boney prominences is measured. The flexed shoulder identifies the side that is being scored. A clearing exam is administered at the end of the shoulder mobility test. This movement is not scored and is simply performed to observe a pain response. If pain is noted, a positive is recorded and a score of zero is given for the entire shoulder mobility test.

Active Straight Leg Raise – The active straight leg raise test the ability to disassociate the lower extremity while maintaining stability in the torso. The active straight leg raise assesses active hamstring and gastroc-soleus flexibility while maintaining a stable pelvis and active extension of the opposite leg. This test is completed by having the subject lay supine with the arms in an anatomical position and head flat on the floor. The 2 x 6 board is placed under the knees. The mid-point between the anterior superior iliac spine (ASIS) and mid-point of the patella is measured. The dowel is placed at this position perpendicular to the ground. The subject lifts the test leg with a dorsiflexed ankle and an extended knee. During the entire test, the opposite knee should remain in contact with the board, the toes should remain pointed upward, and the head remain flat on the floor. Once the end range position is achieved, and the malleolus is located past the dowel, then the score is recorded according to the criteria. If the malleolus does not pass the dowel, then the dowel is aligned along the medial malleolus of the test leg perpendicular to the floor and scored according to the criteria. During the active straight leg raise, the flexed hip identifies the side being scored. The leg on the floor should not externally rotate at the hip. Both knees should remain extended and the knee on the extended hip always is to touch the 2 x 6 board.

Trunk Stability Push-Up – The trunk stability push-up is used in the FMS to test the ability to stabilize the spine in an anterior and posterior plane during a closed-chain upper body movement. This test assesses trunk stability in the sagittal place while a symmetrical upper-extremity motion is performed. The subject begins in a prone position with the feet together. The hands are then placed shoulder width apart at the appropriate position according to the criteria. The knees are fully extended and the ankles are dorsiflexed. The subject is asked to perform one push-up in this position. The body is to be lifted as a single unit. There should not be a lag in the lumbar spine when performing this push-up. If the individual cannot perform a push-up in this position, the hands are lowered to the appropriate position according to the criteria. A clearing exam is performed at the end of the trunk stability push-up test. This movement is not scored. It is performed to observe a pain response. If pain is produced, a positive is recorded and a score of zero is given to the entire push-up test. This clearing exam is necessary because back pain can sometimes go undetected by movement screening. The subject will lie on their stomach with both hands beneath their shoulders. They will press their chest off the floor by extending the elbows, arching their back as much as they can. If they feel pain, they do not clear the exam. During the truck stability push up, the subject should lift their body as a unit. They should maintain the original hand position and the hands should not slide down when they prepare to lift. It is important to make sure that their chest and stomach come off the floor at the same instance.

Rotary Stability – This test is used in the FMS to assess a complex movement requiring proper neuromuscular coordination and energy transfer from one segment of the body to another through the torso. It assesses multi-plane trunk stability during a combined upper and lower extremity motion. The subject starts in a quadruped position with their shoulders and hips at 90 degrees relative to the torso. The knees are positioned at 90 degrees and the ankles are dorsiflexed. The 2 x 6 board is placed between the knees and hands so they are in contact with the board. The subject then flexes the shoulder and extends the same side hip and knee. The elbow, hand, torso, and knee should remain in line with the 2 x 6 board while lifted. The same shoulder is extended and the knee flexed until they touch. This movement is performed bilaterally and if a score of 3 is not attained, the subject performs a diagonal pattern using the opposite shoulder and hip. A clearing exam is performed at the end of the test. If the subject feels pain, a score of 0 is given for the entire rotary stability test. For the clearing exam, the subject should be in a hands and knee position. They should keep their hands on the floor and rock back to their heels. The subject then lowers their chest to the knees with their arms reaching in front of them. It should be noted if the subject feels any pain performing this test.

Strength/Power Assessment

The Associate Head Strength and Conditioning coach certified by the NSCA and CSCCa collected the strength/power measure. He has 11 years experience as strength and conditioning coach and is currently associated with the participants that are to be used for the study. The strength/power measure was collected by assessing each athlete's maximum lift on the bench press, back squat, and power clean. All three lifts used the protocol and lifting techniques provided by the National Strength and Conditioning Association in the Essentials of Strength Training and Conditioning (2). This strength/power value was collected at the end of summer conditioning prior to the competitive season. All strength/power values were correlated with FMS scores.

Statistical Analysis

To determine the strength and direction of the association between FMS scores and strength/power, SPSS 17.0 was utilized to first calculate the Pearson correlations between the FMS composite score and each separate strength/power value and then to conduct non-directional t-tests to determine if the correlations were statistically significantly different from zero (8). The relationship between FMS and strength/power was investigated as two continuous variables. SPSS runs a significant test for the correlations if they are significantly different from zero (8). Because a correlation analysis is significantly different from zero, it is indicated that a relationship exists but does not necessarily suggest the strength of the relationship.

<u>Results</u>

The relationship between the FMS scores and strength/power was examined with all 97 players that participated during 2009-2010. The correlation between the FMS composite score and the bench press measure was found to be significant at the 0.01 level ($r = -0.299$, $t=-3.102$, $p < 0.01$). Using Fisher's r to Z transformation, a 95% confidence interval was calculated: (- 0.564, -0.109). These two variables are negatively correlated with each other; as FMS increases, the bench press decreases, and vice versa. The FMS composite score was also found to be significantly negatively correlated with the back squat measure ($r = -0.261$, $t = -2.663$, $p < 0.01$, 95% CI: (-0.509, -0.065)). The FMS composite score and the power clean measure was not negatively correlated with each other ($r = -0.156$) $p = .124$ (Refer to Figure 4.1).

At the .01 level, there was a significant negative correlation between FMS composite score and bench press ($r = -0.299$) $p=.003$. The higher the FMS score, the lower the bench press max. At the .01 level, there was significant negative correlation between FMS composite score and back squat ($r = -0.261$) $p=.010$. The higher the FMS score, the lower the back squat. At the

0.01 level, there was not a significant correlation between FMS composite score and power clean ($r = -0.156$) $p=.124$. However, the correlation is negative indicating the higher the FMS the lower the power clean. (See Figure 4.1, 4.2, 4.3, and 4.4)

		FMS Composite Score	Bench Press	Back Squat	Power Clean
FMS Composite Score	Pearson Correlation	1	-.299**	-.261**	-.156
	Sig. (2-tailed)		.003	.010	.124
	N	98	98	97	98
Bench Press	Pearson Correlation	-.299**	1	.812**	.780**
	Sig. (2-tailed)	.003		.000	.000
	N	98	127	124	127
Back Squat	Pearson Correlation	-.261**	.812**	1	.806**
	Sig. (2-tailed)	.010	.000		.000
	N	97	124	124	124
Power Clean	Pearson Correlation	-.156	.780**	.806**	1
	Sig. (2-tailed)	.124	.000	.000	
	N	98	127	124	127

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4.1 Correlations of the FMS Composite Score with Bench Press, Back Squat, and Power Clean

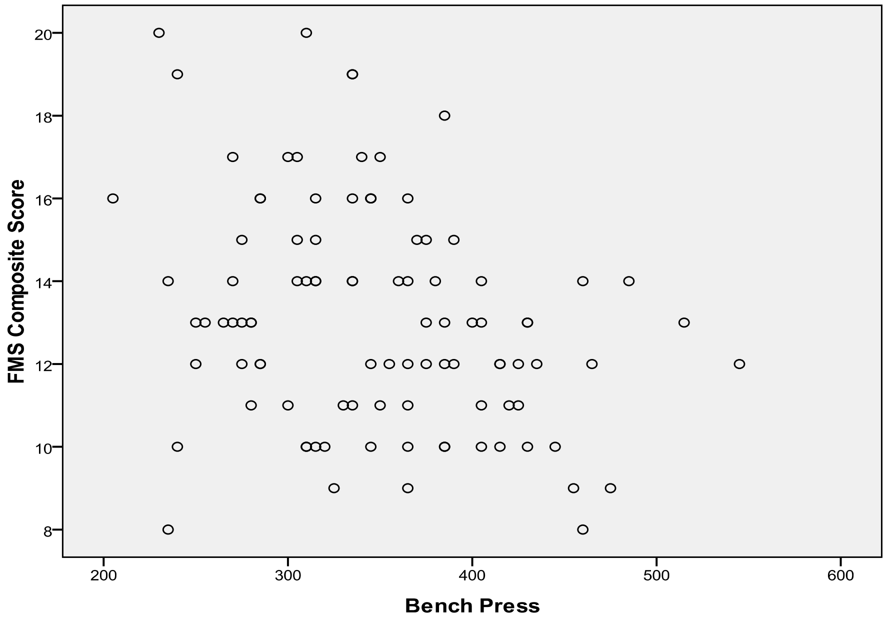

Figure 4.2 Scatter plots of FMS scores and the bench press

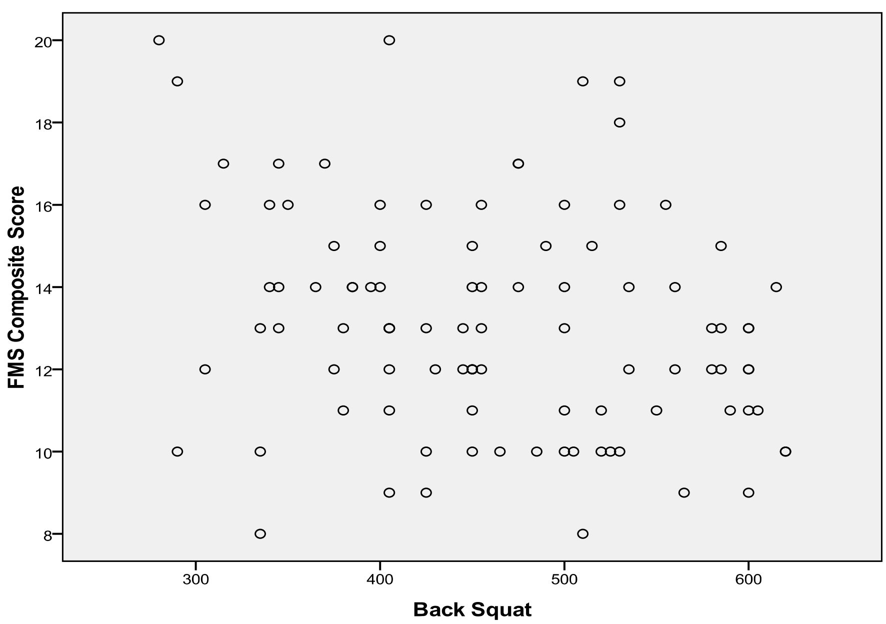

Figure 4.3 Scatter plots of FMS scores and the back squat

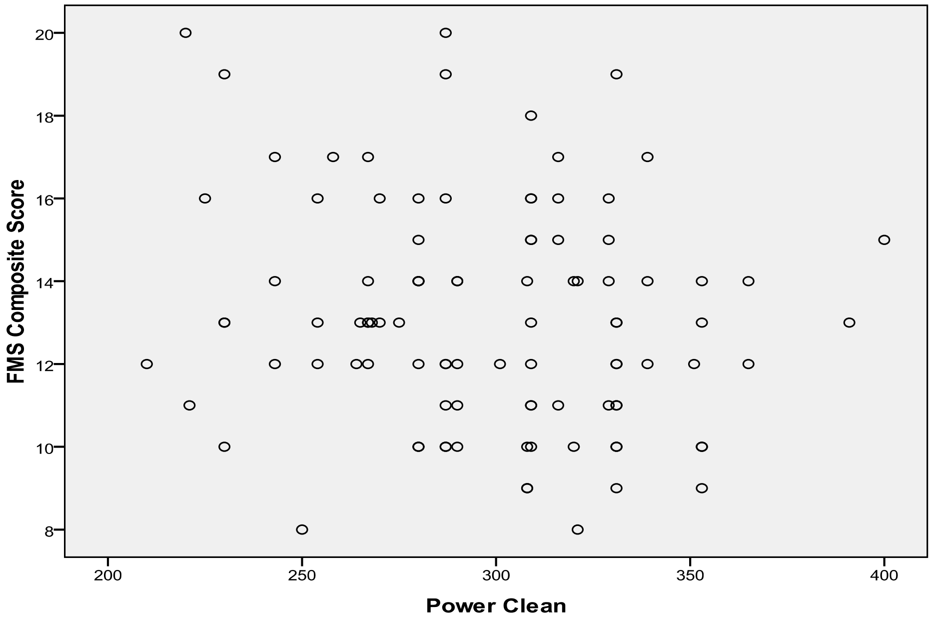

Figure 4.4 Scatter plots of FMS scores and the power clean

Discussion

The sport of football is predicated on the development of strength and power. Training football athletes concentrates on this premise and the physilogical adaptations to the muscle that are needed to produce force quickly. It is also apparent that one of the fundamental adaptations to resistance training is an increase in muscle mass. This occurs by enlargement of muscle fibers (hypertrophy) and the benefit of an increased cross-sectional area of the muscle fibers is an increased ability to develop force (2). Football athletes train with a variety of intense exercises to promote muscle adaptations and improve their physical performance. A common adage of bigger, faster, stronger is a manstra that is espoused by most strength and conditioning personnel. Likewise football coaches expect athletes to increase their strength outputs as they progress in the program. Any drop in performance is critized by coaches as a deterioration of functioning in their athletes. Likewise, the intense training and strengthening of the muscle may proceed without focusing on range of motion (ROM) and developing an accelerated degree of tonus in the muscle. This development allows the athlete to generate speed and force quickly in major muscle groups used to perform the bench press, back squat, and power clean. However, it appears in our study that functional movement as measured by the FMS does not generalize specifically to strength/power produced by these lifts. The FMS was designed as a screening test to determine deficiencies and imbalances in movements not strength or power output. In spite of imbalances, the athlete can still genreate an adequate amount of strength/power to perform the standard football lifts. This was contrary to what was anticipated and appears that the muscle function can be strengthened to produce force even though functional flexibility may be compromised by asymmetries and imbalances. This is an important finding for strength coaches and athletic trainiers because a primary goal of any developmental program is to maximize each athletes potential while keeping them injury free. In response to the coaches concern that athletes aren't getting stronger, it is essential to emphasize ROM and injury prevention while focusing on developing strength. Therefore, training programs should emphasize increasing range of motion while developing strength/power. In this manner the term function or functional is specific to movements that are required in football such as the wide reciever extending themselves to catch a ball that is beyond their reach and absorbing contact in a precarious position. The athlete needs to be strong to jump, run, or absorb the hit while being flexible and functional enough to extend their torso to make the catch. From this context, the assessment of function prior to conditioning is a valuable element for all coaches in order to determine initial levels for training as well as detecting areas of weakness or potential problem areas in the athletes development. Although the FMS is a relatively new instrument, essential information is provided on basic movement patterns which can identity areas of weakness (10). This was evident in a previous study with professional football players indicating that the higher the FMS composite score, the less likely a serious injury would occur (4). These are both important findings because strength coaches and athletic trainers can conclude that just because an athlete is strong and powerful does not necesarrily mean they are at their full potential for resisting an injury. In contrast, the strength and conditioning coach should use the FMS not as a cause and effect measure but as an indicator of performance areas that need to be addressed in the athletes conditioning. Thus, the already powerful athlete should incorporate functional movements to maximize range of motion (ROM) as well as maintaining and improving muscle tonus that is used to generate strength. This is supported in earlier research that indicates that adequate levels of flexibility and strength are necessary for optimal performance (7). Further, an argument can be made that flexibility is more essential for athletes engaged in sports that involve extreme ranges of motion (e.g., football) at extreme speeds (2).

Functionally, the ability to maximize force through the ROM should lead to increased levels of strength and power production and ultimately a stronger, more explosive athlete. Conversly, the aymmetries and imbalances will ultimately expose the athlete to potential injury risks which will ultimately hinder the athletes developmental process and incremental increases in strength/power that go hand-in-hand with increased maturity and sustained training from the beginning of their freshman year to the completion of their athletic performance.

Practical Applications

The findings from this investigation with the FMS can be added with previous findings in order to develop more individualized strength and injury prevention programs for athletes. It can also be concluded that optimal training will address both the strength/power development along with improving functional movement and range of motion. These finding contradicts convential wisdom that programs should focus on getting athletes big and strong. Programs may not be ideal if functional movement remains unchanged and athletes get big and strong but improvements are not made in their range of motion (ROM). While it is important for conditioning programs to improve performance, it is equally important to address injury prevention. If programs can develop athletes strenth/power as well as increase their functional ability, it should translate into improved performance. Optimal program goals should focus on developing and improving both functional movement and stength/power in order to assure athletes reach their full potential.

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CHAPTER 5

SUMMARY AND CONCLUSIONS

Football continues to remain very popular in the United States. Football has evolved over the years with the advances in protective equipment, training regimens, and sports medicine and continues to require athletes of various sizes, abilities, and functional performance levels to perform various techniques and skills on the field. As the sport continues to evolve, it remains important to investigate mechanism and procedures that can potentially limit or prevent injury and maximize athletic development. Football is a complex game with many external factors involved on each play and strength and conditioning and sports medicine programs should be developed accordingly. Each program should be complex, addressing several components and factors in order to attempt injury prevention and maximize athletic performance.

The first step in possible prevention or decreases in injury, it is essential to evaluate all components of functioning which may facilitate an injury. More importantly the ability to define and understand specific injury risk factors may provide vital information to trainers and coaches that could be incorporated to decrease or prevent injury and maximize athletic performance. In the sport of football, injury prevention is a primary component of a training program in addition to improving a player's strength, flexibility, power, and overall performance. The ability to identify potential weaknesses in player's functional capacity can provide the athletic trainer and strength and conditioning professional with the capabilities to strengthen compromised areas as well as improving movement patterns and performance that possibly reduce injury. Therefore, the primary aim of this research was to determine the relationship between college football players functional movement screen score, strength/power, and injury rates.

Two individual studies were completed during the investigation and each involved the use of the functional movement screen with college football players with one focusing on the relationship between the functional movement screen scores and injury and the second focusing on the relationship between the functional movement screen scores and strength/power.

The functional movement screen was found to show some potential as an identifier in predicting significant injuries (as defined in this investigation) of 10 or more days out. Athletes with a lower FMS score were found to be more likely to sustain a significant injury if they scored 11 or less. It was concluded that a cut off score of 11 or less suggests limitations in functional movement patterns, weaknesses, or asymmetries that increase the athlete's susceptibility to injury, thus limiting performance.

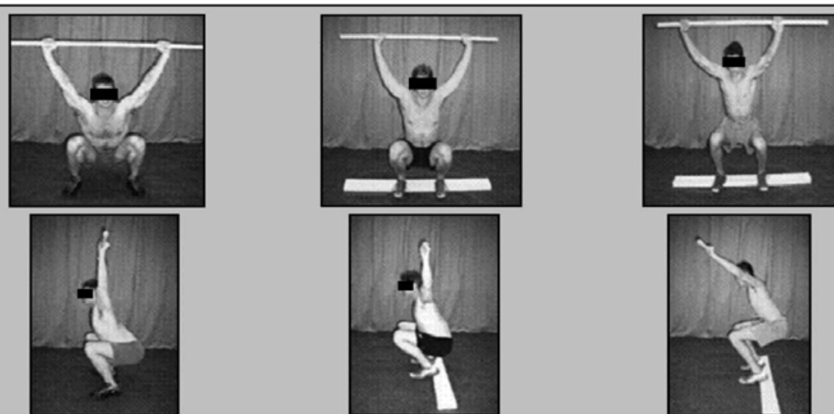
APPENDIX A

THE FUNCTIONAL MOVEMENT SCREEN

Functional Movement Screen : Deep Squat

Frontal View

Sagittal View

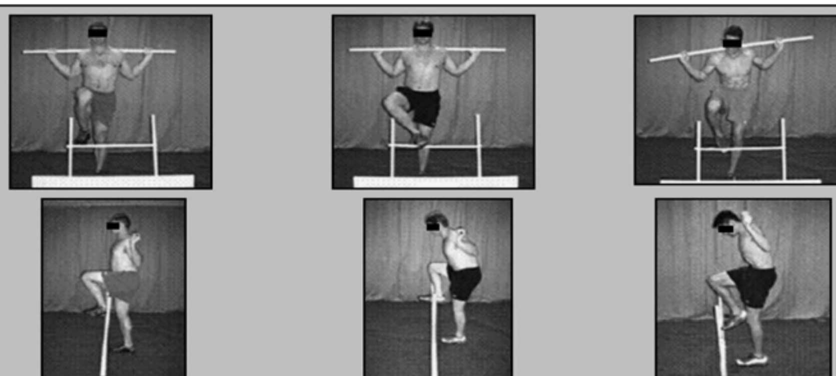


Score	3	2 (Performed with heels on 2x6 board)	1 (Performed with heels on 2x6 board)
Criteria	•Upper torso is parallel with tibia or toward vertical •Femur below horizontal •Knees are aligned over feet •Dowel does not extend past feet	•Upper torso is parallel with tibia or toward vertical •Femur is below horizontal •Knees are aligned over feet •Dowel does not extend past feet	•Tibia and upper torso are not parallel (remain upright) •Femur is not below horizontal •Knees are not aligned over feet •Lumbar flexion is noted

Functional Movement Screen : Hurdle Step

Frontal View

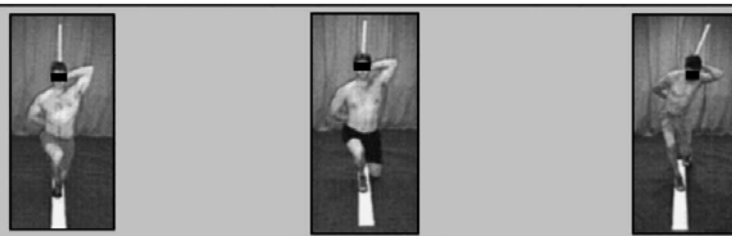
Sagittal View



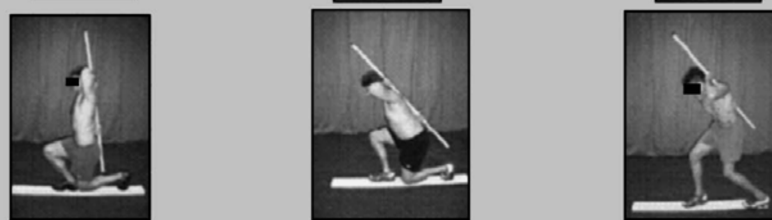
Score	3	2	1
Criteria	•Hips, knees and ankles remain aligned in the sagittal plane •Minimal to no movement is noted in the lumbar spine •Dowel and hurdle remain parallel •Foot remains dorsiflexed	•Alignment is lost between hips, knees and ankles •Movement is noted in lumbar spine •Dowell and hurdle do not remain parallel	•Contact between foot and hurdle •Loss of balanced is noted

Functional Movement Screen : In-Line Lunge

Frontal View



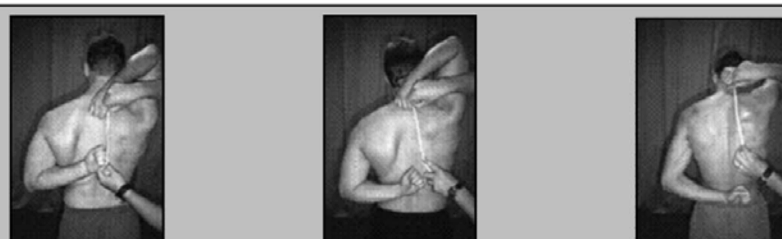
Sagittal View



Score	3	2	1
Criteria	•Dowel contacts remain with L-spine extension (dowel touches head, thoracic spine and sacrum) •No torso movement is noted •Dowel and feet remain in sagittal plane •Knee touches board behind heel of front foot	•Dowel contacts do not remain with L-spine extension •Movement is noted in torso •Dowel and feet do not remain in sagittal plane •Knee does not touch behind heel of front foot	•Loss of balance is noted •Inability to place hands in proper position

Functional Movement Screen : Shoulder Mobility

Frontal View



Score	3	2	1
Criteria	•Fists are within one hand length	•Fists are within one and a half hand lengths	•Fists are not within one and a half hand lengths

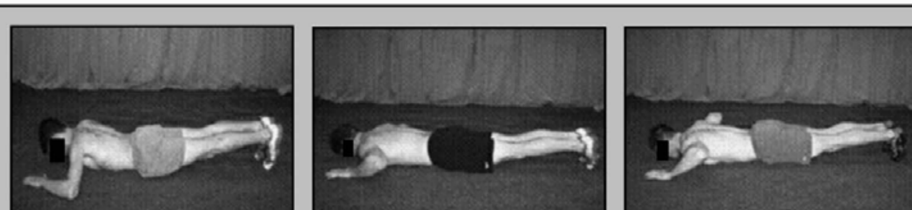
Functional Movement Screen : Active Straight Leg Raise

Sagittal View

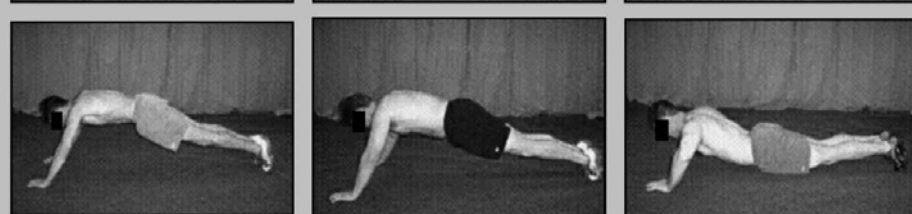
	3	2	1
Score	3	2	1
Criteria	•Ankle/Dowel resides between mid-thigh and ASIS •Opposite hip remains neutral (does not externally rotate), toes remain pointing up •Knees remain in contact with board	•Ankle/Dowel resides between mid-thigh and mid-patella	•Ankle/Dowel resides below mid-patella

Functional Movement Screen : Push Up

Starting position

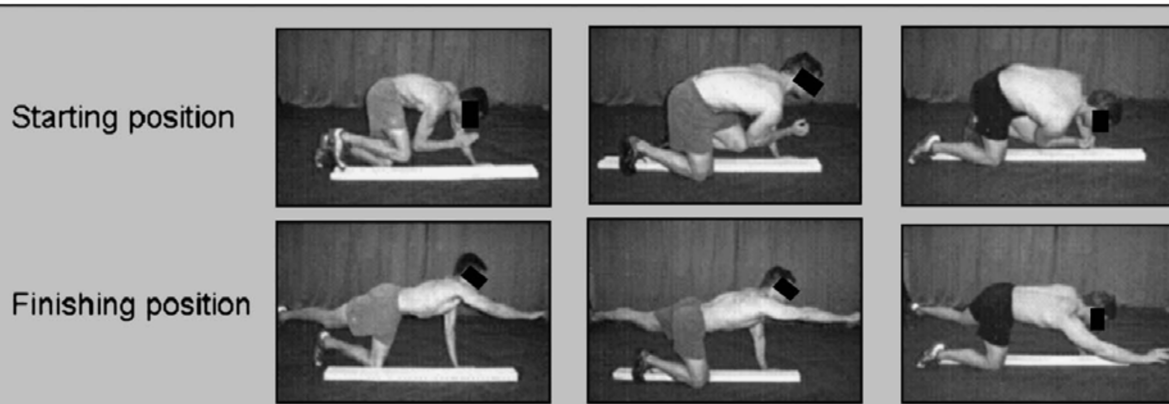


Finishing position



	3	2	1
Score	3	2	1
Criteria	•Males perform one rep. with thumbs aligned with forehead •Females perform one rep. with thumbs aligned with chin •Body is lifted as one unit (no lag in lumbar spine) •Feet remain dorsiflexed	•Males perform one rep. with thumbs aligned with chin •Females perform one rep. with thumbs aligned with clavicle •Body is lifted as one unit •Feet remain dorsiflexed	•Males are unable to perform one rep. with hands aligned with chin •Females are unable to perform one rep. with thumb aligned with clavicle

Functional Movement Screen : Rotary Stability



Score	3	2	1
Criteria	•Performs one correct unilateral repetition while keeping spine parallel to board •Knee and elbow touch in line over the board	•Performs one correct diagonal repetition while keeping spine parallel to board •Knee and elbow touch in line over the board •Minimal trunk flexion	•Inability to perform diagonal repetition

Functional Movement Screen : Clearing Exams