

Determining a Relationship Between Posterior Chain Flexibility and Linear Sprint Speed

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ABSTRACT

One very common axiom amongst Strength and Conditioning Professionals and Athletic Performance Coaches is that the “least flexible athletes usually produce the fastest 40-yard dash times.” Flexibility, in this case specifically refers to posterior chain flexibility (PCF). This is usually measured by athletes’ ability to perform a sit-and-reach test. This train of thought has been widely accepted within the human performance professions, even though it is void of any scientific investigation or measured validity. The purpose of this study is to determine if there is a relationship between posterior chain flexibility using the sit-and-reach test and speed in the 40-yard dash.

All test subjects were male between the ages of 18-22, and members of a Division I university football team. All 95 test subjects had participated in at least one semester of a strength and conditioning program designed by Certified Strength and Conditioning Specialists. Similar of the study done by Johnson (2001), each athlete was placed in a group based on position, “line of scrimmage groups” (LOS), “Skill group” (receivers, cornerbacks, rover linebackers, whip linebackers, and safeties), “Combo group” (inside linebackers, tight ends, quarterbacks, tailbacks, fullbacks, and defensive ends), “Specialist group” (place- kickers, kick-off specialists, holders, and punters).

Each test subject was tested in the 40-yard dash, the sit-and-reach flexibility test, as well as other tests for strength and power such as the bench press, front squat, push jerk, power clean, vertical jump, and agility tests. Body weight and height was also measured.

This study used a simple linear regression on the data where the Sit-and-Reach test results were the dependent variable and the subjects timed results in a 40 yard dash was the independent variable. There appears to be no significant relationship between a low flexibility score and the sprint speed of an athlete for the entire group population.

The results also show that there is no significant relationship between flexibility of the posterior chain and linear speed as measured in the 40-yard dash when looking at football players that fall under the Combo, Skill, or LOS position groups. There was however a significant relationship for the specialist group. The theory that the “least flexible athletes usually produce the fastest 40-yard dash times” is not true for those specific groups.

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Chapter I

Introduction

The value that our American society places on organized athletics, at all levels, has increased tremendously over the past 60 years since World War II. This is evidenced not only in the amount of media coverage and production, but also in the monetary increases in the value of the professional franchises, in the cost of the admission tickets, and most notably, in the increases of the coaches' and players' salaries. The increases in costs, salaries, and revenue production have created many occupational opportunities, among which are the sports performance professionals who provide instruction and further development to athletes at the highest level of competition.

Over the past few years there has been an increasing interest within large scale media and fans watching athletes perform at the National Football League (NFL) Combines testing facility. This multi-faceted testing of physical and mental capabilities is used as the barometer, and in many cases, a final evaluation of a players' ability to determine if they can compete at the professional level within the NFL. An athlete's performance at this combine can mean the difference between a multimillion dollar contract, and simply being eliminated from any future career as a professional athlete. Here is where the sports performance professional can mean the difference for many future players. If they can aid the player in achieving more strength, speed, or agility, it might mean the difference between a first or second round draft pick and not being drafted at all.

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Perhaps the one test in this “combine process” that serves as the benchmark of physical performance, especially with the football skill positions of offensive backs, wide receivers and defensive backs, is the 40-yard dash. It is the primary test for straight ahead speed in evaluating a player’s ability to perform, to earn a possible starting position, and overall potential to move to a higher level of playing. The 40-yard dash is perhaps the most widely accepted and paramount tool that is used to evaluate the sprinting speed of American football players at all levels of the game (Mayhew, Wolfe, & McCormick 1987). Johnson (2001) found in his study of 105 National Collegiate Athletic Association (NCAA) Division I football players that the results of the 40-yard dash tests was the premier determining factor for specific groups of athletes within his tests subjects. The role of the 40-yard dash time is further documented by Gough (2006) in the National Strength and Conditioning Association journal concerning the use of the timed 40-yard dash by college recruiting staffs and awarding of potential college scholarships.

Obviously, there are multiple factors that affect an athletes’ performance and results in their 40-yard sprint times. Body size, strength, prior experience, age, maturation, and physical training are among these. Most of these factors can be quantified and tested, and the results can be correlated to the performance. One very common axiom amongst Strength and Conditioning Professionals and Athletic Performance Coaches is that the “least flexible athletes usually produce the fastest 40-yard dash times.” Flexibility, in this case specifically refers to posterior chain flexibility (PCF). This is range of motion of the torso into the anterior plane of movement, demonstrating the overall mobility of the gastrocnemius group, hamstring group, anterior pelvic tilt, lumbar spinal area, and upper

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thoracic regions. This is usually measured by athletes' ability to perform a sit-and-reach test. This train of thought has been widely accepted within the human performance professions, even though it is void of any scientific investigation or measured validity. Along with this initial axiom is the added acceptance of the idea that in order to increase athletes' speed and lower the resultant time in a 40-yard dash time trial, athletes will need to train in exercises that inadvertently decrease their flexibility, and hence decrease their results on the sit-and-reach test.

Purpose of the Study

As stated by Johnson (2001), the 40-yard dash plays a large role in evaluating a player for potential playing time and ability to move on to the next level of competition. By having a better understanding of some of the factors that play a role in running the 40-yard dash, Strength and Conditioning Professionals can better train their athletes for success. The purpose of this study is to determine if there is a relationship between posterior chain flexibility using the sit-and-reach test and speed in the 40-yard dash.

Justification of the Study

Although Strength and Conditioning Coaches at all levels perform certain tests to evaluate their athletes' progress within their programs, there exists no empirical data or study that correlates the speed as measured in a 40-yard dash time trial to the body's flexibility as measured by the sit-and-reach flexibility test.

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Significance of the Study

The ability of Strength and Conditioning professionals to determine traits that help increase an athlete's performance is essential to creating effective training regimens. This study was designed to determine if one single element of athletic performance has a direct correlation to another, namely if a low score in the sit-and-reach test is an indicator of a fast time in the 40-yard dash. Strength and Conditioning professionals strive to create as sport specific of a training regimen as possible and data collected from this study will aid in creating more effective training protocols for those sports that utilize the 40-yard dash as a measure of performance.

Statement of the Problem

The athletic community, which includes Strength and Conditioning professionals, Professional Coaches, Athletic Administrators and Sports Franchise Owners, spends a great deal of money, time, and expertise in evaluating the athletic potential of an individual. Within all levels of organized football, the 40-yard dash time has been utilized as one of the key factors in performance prediction. Finding trends and having a greater understanding of what factors play into an athlete's performance can help them create more effective training protocols as well as help predict performance. Hence, by determining what physical factors actually influence 40-yard dash times, professionals can greater enhance future sports training protocols.

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Research Hypothesis

Ho: There is no significant correlation between an athlete's posterior chain flexibility (as measured with the Sit-and-reach Test) and their speed over a linear distance (as measured with the 40-yard dash times).

Limitations

For the purpose of this study, subjects were selected from the pool of Varsity football players from an NCAA Division I university football program. The subjects were members of the varsity football team for a minimum of 1 semester, and had undergone the standard conditioning and strength training programs as administered by the Associate Director of Sports Performance. Test results for both the 40-yard dash and the sit-and-reach flexibility test were compiled over a period of 1 week during the physical testing portion of the program. This was accomplished during the spring semester of the academic year.

Definitions

Speed: As defined in this study, is the “displacement per unit time and is typically quantified as the time taken to move over a fixed distance” (Johnson, 2001, p.7). For the purposes of this study, speed is limited in the amount of time taken to move over a distance of 40-yards.

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Flexibility: As defined by Alter (1998), “is the ability to move muscles and joints through their full range of motion”. For the purposes of this study, flexibility is limited to the lower extremities, lower trunk, and upper torso areas of the body.

Posterior Chain: Those areas of the human body that include the lumbar region, the gluteus maximus, hamstrings, hips, posterior knee, and posterior calf regions.

Sit-and-Reach Test: Utilized by professional Physical Educators, Athletic Trainers, and Strength and Conditioning Professional since the inception of the President’s Council on Physical Fitness (1956), it is a measure of lower back and posterior leg flexibility. The test was performed using a standardized testing box and administered in a consistent manner.

Strength and Conditioning Professionals: Individuals who have been certified by the National Strength and Conditioning Association (NSCA) or the Certified Strength and Conditioning Coaches Association (CSCCA) and have undergone the academic and physical testing rigors of those associations.

Chapter II

Review of the Literature

The Purpose of Strength and Conditioning in Athletics

Today's athletes spend a great deal of time, energy and sometimes money on increasing their performance abilities and outcomes. The most effective means in which to achieve these increases is through a structured strength and conditioning program designed to scientifically enhance their performance.

Strength and Conditioning programs today are systematic, sequential, and progressive with a purpose of developing a complete athlete. If a training protocol is planned and implemented correctly there will be an increase in athletic fitness and performance. (Zatsiorsky & Kraemer, 2006) The body's ability to adapt to new stresses or training regimens is one of the most basic biological principles. The main goal of a strength training regimen is for the body to make physical adaptations in order to improve sport performance. The essence of a well-planned strength program is for the strength coach to skillfully combine different training methods that yield better results than what can be achieved through long term exclusive training of one method. This is termed periodization. Periodization can be defined as a logical method of manipulating training variables to increase the potential for achieving performance goals (Stone, Stone, & Sands, 2007). Periodization goals are met by varying the volume, intensity, and exercise selection. A good sports performance coach uses a multi-faceted approach to training that focuses on all the areas involved with sports performance. Too much emphasis in one

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area can lead to major deficiencies in development. Each area must be addressed to achieve maximum athletic potential. The areas are as follows:

Muscular Strength and Power. Muscular strength and power are terms widely used to describe some of the abilities that contribute to athletes' performance. However they are not always used consistently within their scientific definitions. According to Baechle and Earle (2000), strength is the maximum force that a muscle or muscle group can generate with a constant specified velocity. The weight that a person can lift is the oldest quantitative measure of strength we have today. Baechle and Earle (2000), also went on to define power in physics as "the time rate of doing work" (p.35). Work is the product of the force exerted on an object and the distance the object moves in that direction. Therefore one can say that power is work divided by time.

The development of these two areas (strength and power) requires the greatest number of exercises and the greatest amount of time within the overall conditioning program. The two components are, however, key elements to increasing an athlete's potential in all form of sports performance.

Nutrition. In athletics, as in everyday life, proper nutrition provides the human body with the necessary fuel for all performance. Proper intake of healthy food can be a major factor in the body making performance gains. According to Zatsiorsky and Kraemer (2006) strength training activates the synthesis of contractile muscle proteins and causes muscle fiber hypertrophy. This can only happen when there are sufficient substances ingested by the athlete for growth and repair of the muscle fibers.

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Muscular Endurance. As defined by Moran and McGlynn (2000), endurance is the ability of a muscle or muscle group to produce force continually over a period of time. This can be measured by the number of repetitions of the movement or skill. A single repetition of an exercise is a measure of strength, i.e. an athlete can do 1 pull up. To an athlete that can do 25 pull ups, this is a measure of endurance. Many anaerobic sports require muscular endurance performances that require near maximal force for a short period of time. Sprinting, rowing, sprint bicycling, and hurdling are examples of this performance. Muscular endurance is also measured in aerobic sports, the difference being the amount of force or strength utilized in the skill is minimal but the number of repetitions is increased as is the time duration of the skill. Distance running, distance swimming, triathlon events, and other aerobic sports are examples of this form of muscular endurance.

Speed Development. Success in many sports is dependent on speed. Up until the 1970's most believed that speed was a genetic quality that could not be improved upon (Dintiman & Ward, 2003) therefore speed training did not exist for team sports, with the exception of track and field. At the university and professional levels coaches recruited quick or fast athletes, rather than improving speed in athletes with superior skills. The 1972 Olympic games changed this philosophy when the American sprinters (who had dominated until this point) were beaten in the 100-meter dash. Now genetics are considered only one factor in determining maximum speed potential of an athlete. Rather than relying on strict natural ability, professionals now take time to assess problematic areas, work on developing sound speed mechanics, and utilize a wide range of stride lengthening and stride frequency drills, all in an effort to improve the speed of the athlete.

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The primary goal is to increase force production throughout the body, so working at a high intensity is key to increasing maximal speed. This triggers the body's neuromuscular system and its ability to recruit a maximal number of muscle fibers (motor units) to fire at a higher/faster rate for the given task. (Dintiman & Ward, 2003)

Agility. Agility, which is also common in most sports, and according to Baechle and Earle (2000) is often more important than simply achieving a high straight line velocity, is an athlete's ability to explosively break, change directions, and accelerate again without losing speed, coordination, and balance. Movement in any restricted space is critical in competition and relies on the athlete's ability to react to what is happening on the field.

Functional Training. Functional training, more than any other aspect of strength and conditioning, contains the most sport-specific exercises and drills. The area of functional training is constantly evolving, incorporating exercises that enhance flexibility, core, balance, strength, and power. These exercises will be as diverse as the sports to which they are applied. With different body movements and motions varying from sport to sport, exercises are developed to help improve strengths and weaknesses of that specific sport, giving functional training its purpose. (Boyle, 2004)

Flexibility. Flexibility plays a vital role in the athlete's ability to perform. To be able to efficiently move and have complete range of motion throughout the body allows for better athletic performance. Athletes' ability to move fluidly and effortlessly is dependent on the flexibility and mobility of the muscles and joints. Although it increases

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athletic potential, another positive aspect associated with flexibility is decreasing risk of musculoskeletal injury (Baechle & Earle, 2000).

Recovery. Recovery, according to Stone, et al. (2007) is the process of the athlete returning to previous resting state prior to next training session. Exercising causes muscle tissue breakdown, depletion of energy stores, and fluid loss. The body repairs, rebuilds and strengthens itself between workouts in conjunction with optimal rest time (Stone, et al. 2007). This is when the body adapts to the stress of the physical work being performed allowing the real training effects and adaptations to take place.

It is assumed that all strength and conditioning professionals will include all of these areas of human performance factors when developing a sound and safe overall program for the athlete. It is for that reason a specific breakdown of how a training regimen is created will not be included in this study.

The General Role of Strength Training and Speed Training in Athletics

It has been proven that when athletes are committed to a scientifically based strength and conditioning regimen, they benefit greatly through increased speed, power, strength, and agility (Weiss & Halupnik, 2013). Strength training develops three different but related types of muscle strength: maximum muscle strength, which is the greatest amount of force utilized in a single contraction; elastic strength, or the ability of the muscle to contract quickly in response to a demand; and muscular endurance which is the ability of the muscle to repeat an action or to maintain force through a greater number of repetitions.

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When examining the literature that specifically investigates the relationship of strength training and increasing sprint speed, few articles address this area directly.

The 40-yard dash has been called into question as to its relevancy in evaluating running speed in football players. Some experts argue that the game of football demands short sprints with quick accelerations, and physical tests that measure this type of activity may be a better determining factor of performance in football. In order to determine the characteristics of sprint performance and acceleration, Brechue, Mayhew, and Piper (2010) used sixty two Division Two Football players with a mean age of approximately 20 years. Acceleration and sprint velocity were determined at 9.1m intervals over a distance of 9.1m, 36.6m, and 54.9m sprints. Testing was done at the end of the winter off-season training programs. The subjects were broken into three testing groups of linemen, linebackers and tight ends (LB-TE), and backs (cornerbacks, receivers, quarterbacks, running backs, and outside linebackers) and their body weight measured. The participants performed 2 timed trials at each sprint distance of 9.1m, 36.6m, and 54.9m in random order. They were give full recovery of 5 minutes between each trial at that distance with a minimum of 3 days between sprint trials. The trials were performed in a competitive atmosphere with 2 experienced coaches timing each lane. The average of the two times was taken unless there was more than 0.08seconds between the two times. Lower body muscular strength was also evaluated with using the 1-repetition maximum (1-RM) in the squat, power clean, and jerk, all one week after the sprint testing took place. The vertical jump (VJ), standing long jump (SLJ), and the standing triple jump (STJ) were all used to assess the athlete's leg power.

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Brechue et al. (2010) found that the relationship between acceleration and velocity at the 9.1 and 18.3m intervals were significantly negatively correlated with sprint interval times and the final 36.6m final sprint time. Similarly in the 54.9 m sprint, acceleration and velocity at the 9.1m and 18.3 m intervals were highly negatively correlated with the sprint interval time and the final 54.9m sprint time. All intervals beyond the initial 9.1m acceleration and velocity become less associated with sprint time. This study found that body mass was moderately significantly positively correlated with sprint interval times, but negatively correlated with acceleration. Lower body strength was highly correlated with sprint time, acceleration and velocity in the 36.6m sprint with the highest acceleration and velocity observed at the 9.1m interval as sprinting requires a high force generation and a stronger athlete should have a greater potential of force generation.

Brechue et al. (2010) concluded that the initial acceleration and velocity at 9.1m-18.3m interval and the athlete's ability to maintain that velocity throughout the sprint were the best indicators of overall sprint performance which was independent of sprint distance, as well as consistent across all positions. This study also found that lower body strength relative to body mass and leg power contributed specifically to initial acceleration. This can also be explained because of the way a football player is trained with an emphasis on first-step explosiveness.

There is an abundance of research that shows the relationship between ground reaction force capabilities, sprinting performance, and the muscle groups that produce this force are that of the lower body. A study done by McBride, Blow, Kirby, Haines, and Dayne (2009) looks at the correlation between the 1 Rep Maximum (1RM) in the squat and sprinting performance at the 5, 10, and 40-yard distances. The subjects used in this study

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were 17 Division 1-AA male football athletes, all of whom had their body mass (BM) measured prior to testing. The back squat was assessed post warm up with successive percentage of predicted 1RM as appropriate. The subjects were given proper instruction as to the depth of the squat (70° knee angle) as measured with a goniometer, and given up to 4 attempts to achieve a 1RM, with rest periods of 3-5 minutes between each attempt. Sprint times were assessed with an infrared timing system and performed on a standard track, with the athlete starting in a 3-point stance. There was a significant correlation found between the 40-yard sprint times and the 1RM/BM and the squat. There was also a significant correlation between the 10-yard sprint and the 1RM/BM, but this correlation was not significant at the 5-yard distance. This study further demonstrated the importance of lower body strength in reaching maximal level sprinting performance.

The General Role of Flexibility Training in Athletics

There is a limited amount of research that explores the effectiveness of stretching. Many clinicians continue to recommend stretching even though there is minimal scientific support to its benefits (Fasen, et al., 2009). The suggested benefits of stretching are an improved athletic performance, as well as functional movement gains. Many clinicians recommend stretching purely because it has maintained a time-honored role in health and fitness (Fasen, et al., 2009). Some research indicates that flexibility is influenced by factors such as age, sex, and training (Monteiro, et al., 2008). The only way to improve flexibility is to have a proper stretching program, according to Fasen et al.(2009) research suggests that stretching be done 5 days a week, each stretch held for 30 seconds, with 3-4 sets of stretching in order to see results. Some research indicates that proprioceptive neuromuscular facilitation (PNF) and contract-relax (CR) stretching may be more

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effective than static stretching. Ballistic stretching tends to be less effective, and some believe causes injury.

A study done by Fasen et al. (2009) was conducted to determine if active stretches were more effective than passive stretches, as well as if adding neuromobilization to active stretches also helped the stretch. The study used 4 common hamstring stretches that are found in general population health clubs as the independent variable. There were 100 test subjects with an age range of 21-57 with a mean age of 33 and mode of 30, Subjects were 45 women and 55 men, with exclusions being hypermobility (initial hamstring length greater than 90°) history of hamstring tear, upper motor neuron disease, lower motor neuron disease, and past participation in formalized stretching programs. All subjects had an initial hamstring length measurement done using a goniometer, with subjects in the supine position and knee angle taken. Subjects then were randomly assigned one of 5 groups, group A- control; group B- 90/90 passive stretch; group C-90/90 active stretching (antagonist contraction); group D-straight leg raise (SLR) active assisted stretch (neuromobilization component of stretch); and group E- SLR passive stretch.

The control group was asked not to change a thing about their training routine for 12 weeks. Groups B, C, D, and E were given assigned stretches to do 3 sets of 30 seconds, 5 days a week, for 12 weeks. The stretches were as follows: Group B- 90/90 passive stretch was performed supine using a strap. The subject flexed the hip until the femur was perpendicular to the ground, then wrapped a strap around the instep to apply force to achieve passive knee extension (see Appendix A, Figure 1). Group C- 90/90 active

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stretch was also performed supine but without a strap. Subject again flexed the hip until femur was perpendicular to the ground and actively applied tension by flexing the quadriceps muscles to extend their knees (see Appendix A, Figure 2). Group D- SLR active assisted stretch was performed supine against a wall with knees extended to 180° with varying hip angles. Subject was asked to bring femur as close to perpendicular to floor as possible. Each subject placed a heel against a corner of a wall and passive tension was applied to the posterior hamstrings. The neuromobilization element of this stretch was when subjects were given a strap to “pump the foot” by alternating dorsi-flexion (see Appendix A, Figure 3) and plantar-flexion (see Appendix A, Figure 4) of the foot. Group E- SLR passive stretch performed the stretch supine against the wall with the knee extended to 180° and performed the same series of stretch as group D with the exception of neuromobilization of pumping the foot and without a strap (see appendix A, Figure 5). All subjects were given demonstrations, 1-on-1 instruction, as well as illustrations as to which hamstring stretch they should be doing. Subjects were tested at the beginning of the 12 weeks then again at week 4, week 8, and finally at week 12.

Fasen et al. (2009) found that both active and passive stretching programs were effective in increasing flexibility when compared to the control group. At the 4 week testing groups C and D and E showed improvements in hamstring flexibility. The 90/90 passive stretch (group B) and the control group showed no improvements at the 4 week testing. After 8 weeks the SLR passive stretch (group E) had the most improvement in hamstring flexibility. Fasen et al. (2009) concluded that PNF stretches seemed to be as beneficial as

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passive stretches and the addition of neuromobilization may be beneficial to hip flexion and knee extension range of motion.

A second study done by Monteiro et al. (2008) looked at the influence that strength training has on flexibility in women. Specifically, Monteiro and his colleagues studied the effect of a 10-week, circuit-based strength training program on 10 different articular movements on sedentary women, ages 34-40. Twenty women participated in the study and were randomly divided into two groups, an experimental group (EG) and a control group (CG). All subjects had no regular physical activity for 6 months prior to the test. The subjects in EG were given a 1 week resistance training familiarization period where they learned the exercises they would be doing within the circuit. The circuit consisted of 7 exercises and followed the American College of Sports Medicine recommendations for novice weight lifters. The circuit exercise order was Free-weight bench press, smith machine squat, anterior wide grip lat pull-down, 45° leg press, 30° incline bench press, hack machine, and abdominal crunch. Each subject in the Experimental group participated in the training 3 days a week with 48 hours between training sessions. There was 100% adherence to the program, and the program weight was progressed throughout the 10 weeks based on the number or reps performed in warm up sets. Test subjects performed a repetition maximum test after the 1-week familiarization period, and again at the end of the 10- week training program. Each subject was given a maximum of 3 attempts to determine a repetition maximum.

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Flexibility was measured at the end of the familiarization period and the 10 articular movements were measured at the shoulder, elbow, knee and hip, and lower back. The measurements were determined based on the exercises selected for the circuit training of the experimental group. When determining the flexibility of a joint the test evaluator assisted the movement until the subject experienced pain, or mechanical limitation of the movement was reached.

Monteiro, et al. (2008) observed that prior to training there was no significant difference between the two groups for body mass, height, age, body mass index, or any of the repetition maximum values, or flexibility tests. After the 10-week training program the experimental group participants saw significant changes in their repetition maximums, ranging between 52.6% in the free weight bench press to as much as 84.2% increase in the abdominal crunch. However the control group showed no significant changes in their repetition maximums on the strength tests. Of the four shoulder flexibility movements only the horizontal adduction demonstrated significant increases with weight training. Elbow and knee flexion did not show a significant change with weight training. Both hip flexion and extension, and trunk flexion and extension showed significant increases with weight training. The control group showed no significant change in any of the flexibility measures.

The results of this test indicate that strength training has a significant effect on flexibility of the hip and trunk but does not affect the flexibility of the elbow or knee, and has only minimal effect on shoulder flexibility. Therefore strength training can increase the range

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of motion of some but not all joints. Perhaps the bigger conclusion can be drawn that there was no significant decrease in range of motion in those subjects in the experimental group.

In sports, flexibility is a major component contributing to skilled performance especially in performance activities such as, dance, diving, and gymnastics where complete joint range of motion is required for aesthetic performance as well as execution of certain movements (Thrash & Kelly, 1987). Joint flexibility is limited by bone configuration, connective tissues elasticity, elasticity of muscles and their fascial sheaths, and skin. Literature shows that flexibility does not exist as a single characteristic of the human body. An individual's flexibility cannot be determined or predicted by composite or single joint tests. A study done by Thrash and Kelly (1987) examined the effects of an 11-week weight training program on the range of motion in the ankle, shoulder joints, and trunk of college-age men.

Thrash and Kelly utilized 13 subjects ranging in age between 18 to 41 years old, who consented to participate in an 11-week (29 sessions) progressive, dynamic weight training program. The exercises used were bench press, dips, curls, behind the neck press, pull-downs, squats, heel raises, and sit-ups. The progression of the training was three sets of eight reps, using free weights (except for pull-down) and was conducted three times a week. Each session lasted about 55 minutes with 48 hours between each training session. The subjects were given proper instruction on lifting techniques with an emphasis on performing each exercise with a full range of motion. The initial training loads were set

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based on the participants being able to perform each set with only the last two reps being difficult. When all reps were considered “easy” the exercise load was increased, and recorded on a day to day basis.

This study used a Leighton flexometer to measure the range of motion in ankle dorsi-flexion, ankle plantar-flexion, trunk flexion, trunk extension, shoulder flexion, and shoulder extension; prior to the 11-week weight training as well as at the completion of the 11-week weight training program. Subjects all had significant gains in each exercise in the strength training program. The results of the flexibility tests showed a significant increase in range of motion with the ankle dorsi-flexion and shoulder extension of +5.5° and +6.7° respectively. All the joints tested increased in range of motion but not significantly.

These studies have shown that despite previous beliefs that strength training decreases flexibility it actually has a positive effect on many joints, thus allowing an increased range of motion and, for many sports, enhanced performance.

The Role of the Sit-and-Reach Test in the Measurement of Flexibility

There are two common instruments that are utilized in measuring forward flexibility and hamstring extensibility in human subjects. The two instruments are the Sit-and-reach Test and the Back Saver Sit-and-reach test. As reported by Lopez-Minarro, Baranda Andujar, and Rodriguez-Garcia (2009), there was no significant difference in concurrent validity between the two tests. In their study of 67 women and 76 men, with mean ages of

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approximately 23 years, the subjects performed standard static stretches for 5 minutes prior to testing. Each subject was then asked to perform three trials of passive straight leg raise (PSLR), a sit-and-reach trial, and a back saver sit-and-reach trial. The tests were performed in random order, with a 5-minute rest between trials. In their analysis, it was determined that thoracic angle measurements between the sit-and-reach and back saver sit-and-reach tests were significant, but forward reach scores, which take into account scapular abduction, spine and hip flexion, and all other anthropometric factors, were not found to have any statistical significant differences.

Since both tests evaluate the hamstring and lower back flexibility, and there was no significant difference between the results, either test would therefore be suited for use. However, historically, the Sit-and-reach tests are used primarily purely because they are easy to administer, do not require specialized skills for the testers, are useful when dealing with large groups, and have been the standard test for decades (Lopez-Minarro, et al., 2009).

The Sit-and-Reach Test was originally chosen by the American Alliance for Health, Physical Education, Recreation & Dance (AAHPERD) for its physical fitness protocol. It is also included in the President's Fitness Challenge and other health-related fitness challenges, and is a moderate measure of hamstring extensibility. Again, this test was utilized due to its ease of administration, and the ability to test large groups of students in a short period of time (Baltaci, Un, Tunay, Besler, & Gerceker, 2003).

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The Role of the 40-Yard Dash Sprint Time in Football

The 40-yard dash has been used in many circles for years as the premier assessment for linear speed among football players of all ages (Gough, 2006). The 40-yard dash assesses more than just linear speed, it also is used by athletic performance professionals to help assess the effects of a conditioning or speed training regimen. It can be used to assess the speed potential of an athlete. For instance if an athlete has a fast 40-yard dash, but does not have proper running techniques, the potential for increasing his speed exists, because the more efficient the running technique the faster the athlete can move (Gough, 2006).

Given the fact that the 40-yard dash times are utilized quite extensively in contemporary football, Johnson performed a study to determine if the testing results of Division I college football players had any carry over role in determining their playing status. Johnson (2001) examined 105 football players from 1994-2000, all of whom had been in the program for at least 4 years. All the subjects were given a classification of “starter” or “non-starter” based on their playing status over those four years. Furthermore the subjects were broken down into three sub categories based on their football playing positions: the Skill group, Combo group, and Line-of-Scrimmage (LOS) group. The Skill group was comprised of receivers, cornerbacks, rover linebackers, whip linebackers, and safeties. The Combo group included the inside linebackers, tight-ends, quarterbacks, tailbacks, fullbacks, and defensive ends. Finally the LOS group was comprised of the offensive linemen, and defensive tackles. This study excluded the specialist group of place-

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kickers, kick-off specialists, holders, and punters because they did not identify with the norms of the three position groups.

Each test subject participated in a battery of tests and had body weight measured. The tests in this study were the bench press, back squat, power clean; push jerk, vertical jump, 40-yard dash, and body weight. Johnson (2001) used a Proc StepDisc statistical procedure to determine the importance of each test in order of highest-to-lowest in terms of differentiating between starters and non-starters on the football team. The order of ranking proved to be different for each group. The Skill group ranking was 1) vertical jump, 2) power clean, 3) 40-yard dash, 4) back squat, 5) bodyweight, 6) push jerk, 7) bench press. The Combo group ranking of importance was 1) 40-yard dash, 2) bodyweight, 3) bench press, 4) back squat, 5) vertical jump, 6) push jerk, 7) power clean. Finally the LOS group was determined to be 1) bodyweight, 2) vertical jump, 3) bench press, 4) back squat, 5) power clean, 6) push jerk, 7) 40-yard dash.

Johnson's(2001) study demonstrates that for at least some of the position groups the 40-yard dash plays a significant role in determining starting players and non- starters.

The Relationship between Flexibility Training and Speed

Sprint running is performed and measured across a wide range of sports. In order for athletes to perform at an optimal level they need to maximize their physiological potential while reducing their injuries. Implementing a flexibility training regimen can aid in the fulfillment of both (Blazeovich, 2001). Most athletes have a flexibility training

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regimen that runs concurrently with their resistance (lifting or strength training) and speed training, but they still may not reach peak sprint performance. Training within a certain movement pattern allows muscle fibers to produce maximum force at the length that is required for that task. The over-stretching of a muscle group may change the optimum length needed for force development. Muscles have the ability to adapt and if they adapt to longer lengths because of frequent stretching, they may adapt to a degree that the length needed for maximum force is altered. While there have been few studies to support this it is possible that excessive flexibility can result in decreased performance, simply because joint laxity caused by over-stretching is associated with an increased rate of injury. Therefore some muscle groups should be stretched less frequently (Blazevich, 2001).

A study done by Winchester , Nelson, Landin, Young, and Schexnayder (2008) was performed in order to determine if the deleterious effects of static stretching (SS) would negate the performance enhancing effects obtained by doing a dynamic warm up (DW). Over recent years the DW has received more attention as it has been found to increase countermovement jumps, height, and rate of force development when compared to a traditional warm-up (Winchester et al., 2008). Winchester's et al. (2008) study used 11 male and 11 female NCAA Division I track sprinters. All subjects performed a DW and then either a SS or a rest or no-stretch (NS) session, the duration of the SS protocol was 10 minutes. Following the stretching or rest period each athlete performed three 40m sprints, with a minimum of 5 minutes of rest between. The 3 times were averaged together as the first 20m, the second 20m, and the whole 40 m. The mean value for each

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distance was used as the athlete's score. The results show that for the first 20m the difference between the SS group and the NS group was not significant. However the second 20m and the entire 40m time were significantly different between the two groups. The major finding in the study was that the group that participated in the SS prior to testing had a decrease of 3% in sprint performance over a distance of 40m. It can be said that pre static stretching may decrease the athlete's performance in the 40m sprint.

Kistler, Walsh, Horn, and Cox, (2012) took this study a little further to determine the effects of static stretching on 60 and 100m sprints. This study used 18 sprinters, hurdlers, horizontal jumpers, pole vaulter, and multi-event athletes, with an approximate age of 20. Kistler, et al. (2012) adopted the same procedures as Winchester et al. (2008) with the athlete performing two 100m timed trial events. Electronic timing gates were set up at 0,20,40,60, and 100m in order to time the athlete throughout the sprint. On the second day of testing the athletes flip flopped who performed SS and who was part of the NS group. Kistler et al. (2012) found that there was a significant difference between the groups in the second 20m of the sprint. However they did not find a significant difference between the two groups over the first 40m sprint as Winchester et al. (2008) did. Finally when looking at the racing distances, Kistler, et al. (2012) found that there was no significant difference over the last 60m of the race.

It is obvious that there needs to be a greater amount of understanding on the relationship between flexibility and sprint speed. The purpose of this study is to determine if there is a

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correlation between baseline flexibility, using the SR test and the linear speed of an athlete, using the 40-yard dash.

Chapter III

Methods

Purpose of the Study

The purpose of this study was to determine if there is a relationship between posterior chain flexibility using the sit-and-reach test and speed in the 40-yard dash.

Participants

All test subjects were male between the ages of 18-22, and members of a Division I university football team. All 95 test subjects had participated in at least one semester of a strength and conditioning program designed by Certified Strength and Conditioning Specialists as certified by the National Strength and Conditioning Association or the Collegiate Strength and Conditioning Coaches Association. Each test subject were tested in the 40-yard dash, the sit-and-reach flexibility test, as well as other tests for strength and power such as the bench press, front squat, push jerk, power clean, vertical jump, and agility tests. Body weight and height was also measured.

Instruments and Apparatus

According to Brechue, et al. (2010) it does not have scientific basis for using it to evaluate football speed, but it is believed to be about as far as a typical football player would have to run on any given play. In today's game with player specialization its relevance is being called into question as the average football play requires shorter sprints of 5-20 yards. The player's ability to accelerate and change directions may be better

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indicator of performance. In any case the 40-yard dash is still considered a good predictor of on field-performance (Brechue, et al., 2010).

The 40-yard dash equipment needed is a flat running surface with start and finish lines marked 40-yards apart. There is to be a minimum of 20 yards beyond the finish line for the athlete to have the space needed to decelerate. Stopwatches or some form of electronic timing mechanism must be consistent throughout the testing.

There are two common types of sit-and-reach tests used in physical fitness testing batteries, those being the Sit-and-reach Test, and the Back Saver Sit-and-reach Test. Both tests evaluate the hamstring and lower back flexibility. There is little evidence supporting that either of these tests adequately measure low back flexibility and only moderately measure hamstring extensibility. Sit-and-reach tests are used to evaluate hamstring extensibility purely because they are easy to administer, do not require specialized skills to administer, and are useful when dealing with large groups (Lopez-Minarro, et al., 2009).

The Sit-and-reach Test was originally chosen by the AAHPERD physical fitness protocol. It is also included in the President's fitness challenge and other health-related fitness challenges, and is a moderate measure of hamstring extensibility (Baltaci, et al., 2003).

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The Back-Saver Sit-and-reach test is similar to the Sit-and-Reach test except that only one leg is extended against the sit-and-reach box while the other is flexed. It primarily tests hamstring extensibility, and is intended to be safer on the spine. The choice of the test to be used is often based on the examiner's preference, ease of use, and professional discipline rather than scientific evidence (Lopez-Minarro, et al., 2009).

The Sit-and-Reach test requires a standardized sit-and-reach box with marked measures, a flat wooden board to place over the knees, and a flat surface for the athlete to sit and stretch upon.

Procedures for Testing

The physical testing session was performed in March of the spring semester, at the conclusion of the 8-week conditioning program. The testing took place on an indoor track facility with 40-yards marked with a start and finish line. Three different athletic coaches were equipped with stop watches to time each individual. Each individual athlete was timed by the same three coaches. The "score" for the athlete's attempt is an average of each of the three times. Each individual performed at least two timed 40-yard dashes, utilizing a period of rest to full recovery time between attempts. The final recorded best time is the lowest average of the two or three trials.

Similar of the study done by Johnson (2001), the "line of scrimmage groups" (LOS) ran two trials of the 40-yard dash. "Skill group" (receivers, cornerbacks, rover linebackers, whip linebackers, and safeties) and "Combo group" (inside linebackers, tight ends,

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quarterbacks, tailbacks, fullbacks, and defensive ends) players were required to perform 3 trials of the 40-yard dash. The differentiation between the groups was based upon the findings by Johnson, in that it was concluded that the 40-yard dash was a significant indicator of playing time by those athletes. Times were recorded to the nearest one hundredth (.01) of a second.

The Sit-and-Reach test was administered on the floor of the weight room. Each athlete was given sufficient time to stretch and prepare for the test. A sit-and-reach box was placed against a wall or secured to ensure it would not be displaced during the stretch. Athletes were instructed to remove their shoes, sit on the floor, and place their feet flat against the box. A flat board was placed over athletes' knees to ensure that their knees remained in full extension and pressed to the floor. A strength coach assisted with keeping the athletes' knees on the ground. With the palms facing down and their hands stacked on top of each other, the athletes reached forward along the measuring line until they reached the furthest point their body allows. Athletes were instructed not to proceed past the point of pain or discomfort. The hands must remain at the same level and one cannot slide farther forward than the other. The stretch must be in a slow controlled manner with no ballistic movements and must be held for a two seconds count in order to be considered a complete attempt (see Appendix A, Figure 6). The athlete was given three attempts to stretch and hold that position with their farthest distance recorded. The scoring was based on the foot line being zero. If athletes could not reach their toes it was recorded as a positive number. Negative numbers were recorded for athletes who could

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reach beyond their toes. All recordings were measured to the nearest one/quarter (.25) inch.

All testing procedures for this study were conducted under the direction of the Associate Athletic Director for Sports Performance and has been collected in a consistent manner.

Data Analysis

Since the problem, as stated, is only examining the relationship between flexibility (independent variable) as a determinant for the predictor of speed in the 40-yard dash (dependent variable), a correlation test was utilized in the interpretation of the data using the statistical software minitab. Further breakdown of the data was done by utilizing the same grouping of positions as did Johnson (2001) with the exception of “special and snappers” which will be grouped under the heading “specialist”.

Chapter IV

Results

The ability of Strength and Conditioning professionals to determine characteristics that help increase an athlete's performance is essential to creating effective training regimens. This study was designed to determine if one single element of athletic performance has a direct correlation to another, namely if a low score in the sit-and-reach test is an indicator of a fast time in the 40-yard dash. To examine this relationship, the null hypothesis was stated that there is no significant correlation between an athlete's posterior chain flexibility (as measured with the Sit-and-reach Test) and their speed over a linear distance (as measured with the 40-yard dash times).

Utilizing the data collected as described in Chapter III, a simple linear regression statistical test was performed on the data. The study examined only one correlation between the results of the Sit-and-reach test (dependent variable) and the subjects' 40 yard dash times (independent variable), for the entire population as well as the sub groups of LOS, Combo, Skill, and Specialist.

Whole Population Group Results

In examining the results of the entire population (n=95), the scatterplot (See Appendix B, Figure 7) represents the data collected for subject's 40 yard dash time (y axis) as compared to their Sit-and-reach score (x axis).

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The results of this scatterplot and data indicate no visible linear regression between the two variables. A linear regression equation was calculated using the statistical analysis software (Minitab). The results indicated that the constant X intercept was 4.88 with a slope of .0174. (Sprint Speed = 4.88 + 0.0174 Sit & Reach). The R^2 value of .176 indicates a non-significant ($p=0.87$) linear relationship between the two variables. This confirms the results of the simple linear regression results that showed no significant correlation exists between the Sit-and-reach score and the sprint speed of the athlete.

LOS Population Group Results

The results of the LOS population ($n=18$) are displayed in the scatterplot (See Appendix B, Figure 8), and represent the data collected for subject's 40 yard dash time (y axis) as compared to their Sit-and-reach score (x axis).

The results of this scatterplot and data for the LOS population indicated no visible linear regression between the two variables. A linear regression equation shows that the constant X intercept was 5.05 with a slope of 0.0218. (Sprint Speed = 4.88 + 0.0218 Sit & Reach). The R^2 value of 0.2387 indicates a non-significant ($p=0.339$) linear relationship between the two variables.

Skill Population Group Results

The results of the Skill population ($n=10$) are displayed in the scatterplot (See Appendix B, Figure 9) and represent the data collected for subject's 40 yard dash time (y axis) as compared to their Sit-and-reach score (x axis)

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The results of this scatterplot and data for the Skill group population indicated no visible linear regression between the two variables. The linear regression equation for the skill group was that the constant X intercept was 4.66 with a slope of 0.0134. (Sprint Speed = $4.66 + 0.0134\text{Sit \& Reach}$). The R^2 value of 0.1816 indicates a non-significant ($p=0.617$) linear relationship between the two variables.

Combo Population Group Results

The results of the Combo population ($n=58$) are displayed in the scatterplot (See Appendix B, Figure 10) and represent the data collected for subject's 40 yard dash time (y axis) as compared to their Sit-and-reach score (x axis).

The results of this scatter plot and data for the Combo group indicated no visible linear regression between the two variables. The linear regression equation for the Combo group was that the constant X intercept was 4.75 with a slope of 0.0117. (Sprint Speed = $4.75 + 0.0117\text{Sit \& Reach}$). The R^2 value of 0.187 indicates a non-significant ($p=0.158$) linear relationship between the two variables.

Specialist Population Group Results

The results of the Specialist population ($n=9$) are displayed in the scatterplot (See Appendix B, Figure 11) and represent the data collected for subject's 40 yard dash time (y axis) as compared to their Sit-and-reach score (x axis).

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The results of this scatterplot and data for the Specialist group indicated that there is a visible linear regression between the two variables. The linear regression equation for the Specialist group was that the constant X intercept was 5.21 with a slope of 0.0477. (Sprint Speed = 5.21 + 0.0477Sit & Reach). The R^2 value of 0.681 indicates a significant ($p=0.043$) linear relationship between the two variables ($p \leq 0.05$).

Chapter V

Discussion, Conclusions, Recommendations,

Introduction

The ability of Strength and Conditioning professionals to determine characteristic that help increase an athlete's performance is essential to creating effective training regimens. This study was designed to determine if one single element of athletic performance has a direct correlation to another, namely if a low score in the sit-and-reach test is an indicator of a fast time in the 40-yard dash. As stated in the introduction the 40-yard dash is the most widely accepted and principal tool used to evaluate the sprinting speed of American football players at all levels of the game (Mayhew et al., 1987).

The purpose of this study was to determine if there is a relationship between posterior chain flexibility using the sit-and-reach test and speed in the 40-yard dash. The results of this study would determine if the axiom amongst Strength and Conditioning Professionals and Athletic Performance Coaches that the "least flexible athletes usually produce the fastest 40-yard dash times" is true or not.

The test subjects were selected from the pool of Varsity football players from an NCAA Division I university football program. The subjects were members of the varsity football team for a minimum of 1 semester, and had undergone the standard conditioning and strength training programs as administered by the Associate Director of Sports Performance. Test results for both the 40-yard dash and the sit-and-reach flexibility test

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were compiled over a period of 1 week during the physical testing portion of the program. This was accomplished in March of the spring semester during the academic year.

Discussion

Many of today's athletes are evaluated in various physical drills and performances in an effort to predict levels of success and continued performance of their sport. Most notably an athlete's speed has been one of the primary determinants for playing time at the NCAA Division I level in the sport of football. As demonstrated in the review of literature, Johnson clearly showed that speed was one of the top three criteria for determining playing status in two (2) out of the three (3) subjects groups within his study. As this research has shown, there are many contributing factors in the development of an individual's speed. Brechue et al. (2010) found a significant correlation between lower body strength and acceleration and velocity. McBride et al. (2009) further specified the relationship of lower body strength, particularly 1 RM/BM and the squat exercise resulted in significant correlation with speed at the 10 yard interval.

The role of individual flexibility as it relates to speed development and performance has been limited up to this point. Fasen et al. (2009) examined the role of stretching as a means of improving flexibility. The result confirmed an increase in lower body flexibility, but there was no direct link to an increase in the athlete's performance as a result of this flexibility gain. Further, research done by Monterio et al. (2008) showed that certain strength training programs produced a significant increase in lower body range of motion and flexibility. Perhaps the most significant study to date is the

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Winchester et al. (2008) research that clearly shows a decrease in speed in those athletes that utilize a static stretching (SS) program prior to timed interval sprints of 20 and 40 meters.

Since it has been confirmed that lower body strength increases speed and speed development, and flexibility and static stretching have shown deleterious effects on speed and speed development, can a correlation be established between speed and low Posterior Chain flexibility scores?

The results reported in Chapter IV utilized a simple linear regression for the test group of 95 NCAA Division I football players. Using the Sit-and-reach test results as the dependent variable and the subjects timed results in a 40 yard dash as the independent variable, there appears to be no significant relationship between a low flexibility score and the sprint speed of an athlete.

The LOS subgroup population (n=18) was examined utilizing the same criteria and statistical software. As a result of their scores, it was found that this group demonstrated no visible linear regression, and showed a non-significant correlation between Posterior Chain flexibility and speed. Also sectioned out of the main population group for analysis was the Skill Group (n=10) and Combo group (n=58). These groups' data showed similar results to the LOS group as well as the population as a whole.

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The Specialist group did show a significant relationship between Sit-and-reach scores and sprint speed ($p=0.043$). One potential explanation for this result is the small number of test subjects ($n=9$). A second explanation for this demonstrated significant correlation could lie in the diverse makeup of the group. According to Johnson (2001), the specialist athletes were not included in his study because they did not identify with the characteristics of the norms of the other 3 groups. Physiologically speaking this group has none of the same characteristics as the Combo, Skill, or LOS group, but some parts of each. Their training as well is more diversified, with different skills needed and training regimens at practice.

Conclusions

On the basis of the results of this study, it would appear that there is no significant relationship between flexibility of the posterior chain and linear speed as measured in the 40-yard dash when looking at football players that fall under the Combo, Skill, or LOS position groups. The theory that the “least flexible athletes usually produce the fastest 40-yard dash times” is not true for these groups. It should be noted that these results are only indicative of the team represented in the current study. However other teams with a similar strength and conditioning regimen could see similar results.

Possible Future Studies

Since speed development occurs over a period of time through constant training, perhaps further examination of this relationship of posterior chain flexibility and speed would be enhanced via a longitudinal study of subjects over a period of time rather than a single

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episodic measurement. Utilizing the same subject criteria, determine first if there is a statistically significant decrease in their Posterior Chain flexibility after participating in a set strength and conditioning program designed by professionals for their specific sport. Secondly, determine if there is a statistically significant increase in the subjects speed over the same period of time and under the same training protocols. Lastly, then determine if there is a significant correlation between the change in Posterior Chain flexibility and the change in speed over a specific training period utilizing a specific training protocol.

Implications for the Strength and Conditioning Professional

This study has shown no significant relationship between flexibility of the posterior chain and linear sprint speed for the general football population. Therefore strength and conditioning professionals would be better to focus on strength development of the lower body, power development, and dynamic stretching rather than static stretching in order to develop linear speed. The current trend of dynamic stretching can continue to be the norm prior to training and competition. However since there is no correlation between Sit-and-Reach scores and sprint speed, static stretching regimes such as PNF (proprioceptive neuromuscular facilitation) stretching, yoga, and other static exercises can be used, with the conditioning professionals discretion, within the training protocol. This would provide the athlete with muscular mobility, joint flexibility, and an exposure to lifelong flexibility.

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Appendix A

Description of Stretches



Figure 1, 90/90 passive group (group B)



Figure 2, 90/90 active group (group C)

Description of Stretches



Figure 3, Straight leg raise (SLR) active assisted group (group D)-Dorsi-flexion



Figure 4, SLR active assisted group (group D)- Plantar-flexion

Description of Stretches



Figure 5, SLR passive group (group E)



Figure 6, Sit-and-Reach Flexibility Test

Appendix B

Statistical Analysis Scatterplots

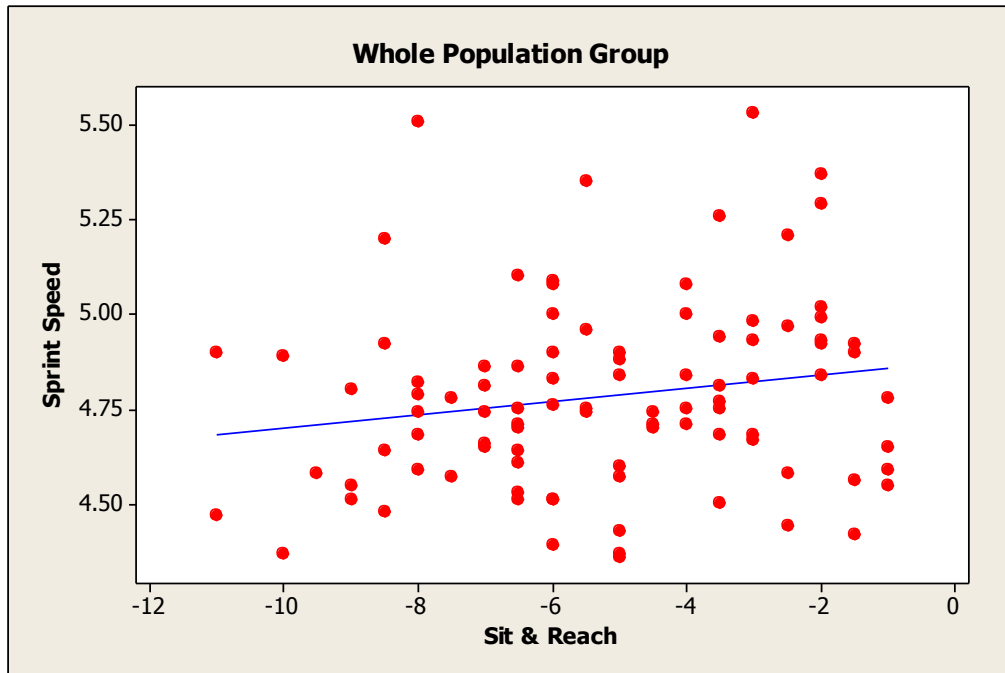


Figure 7, Scatterplot of Whole Population

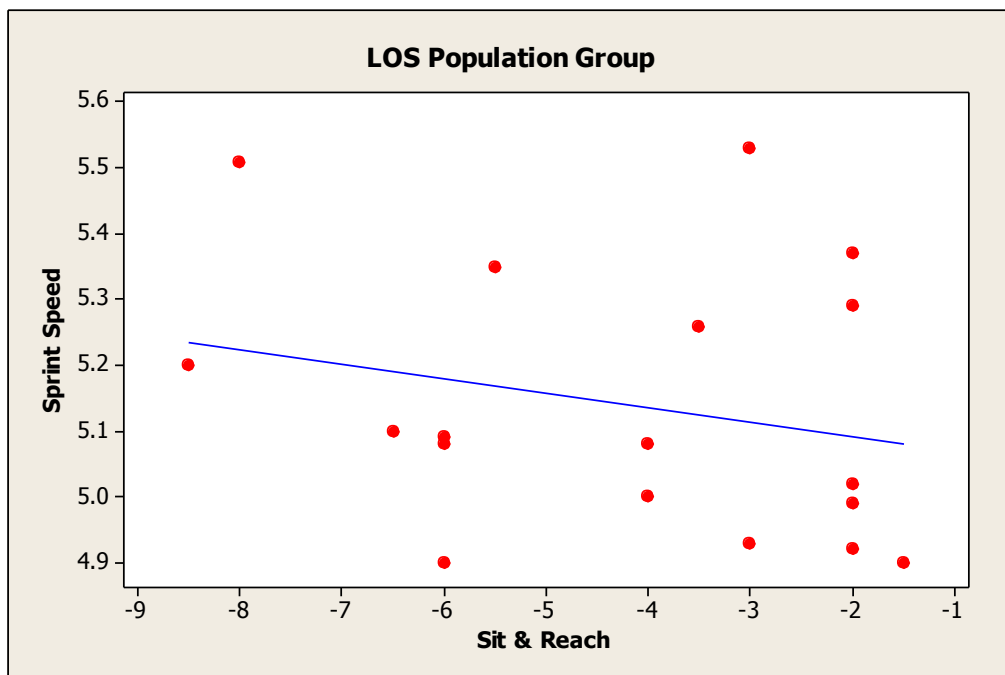


Figure 8, Scatterplot of LOS Population

Statistical Analysis Scatterplots

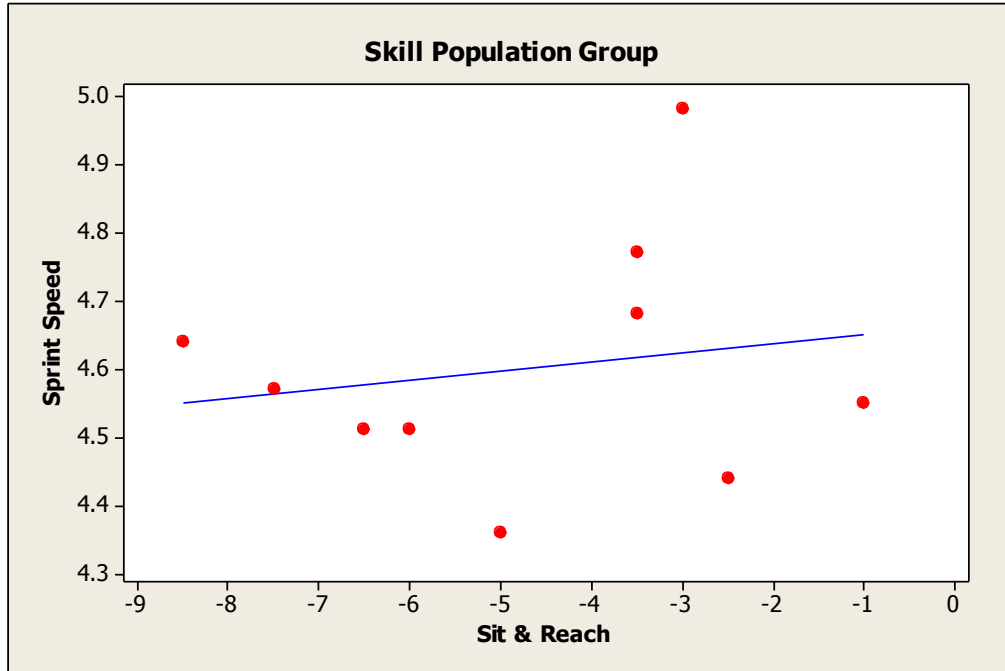


Figure 9, Scatterplot of Skill Population

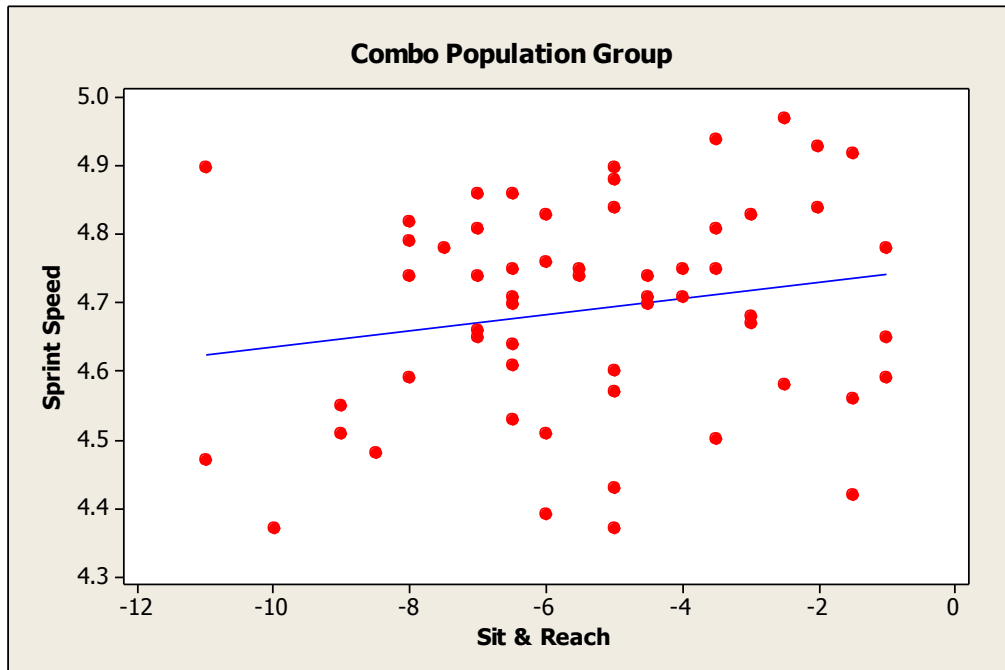


Figure 10, Scatterplot of Combo Population

Statistical Analysis Scatterplots

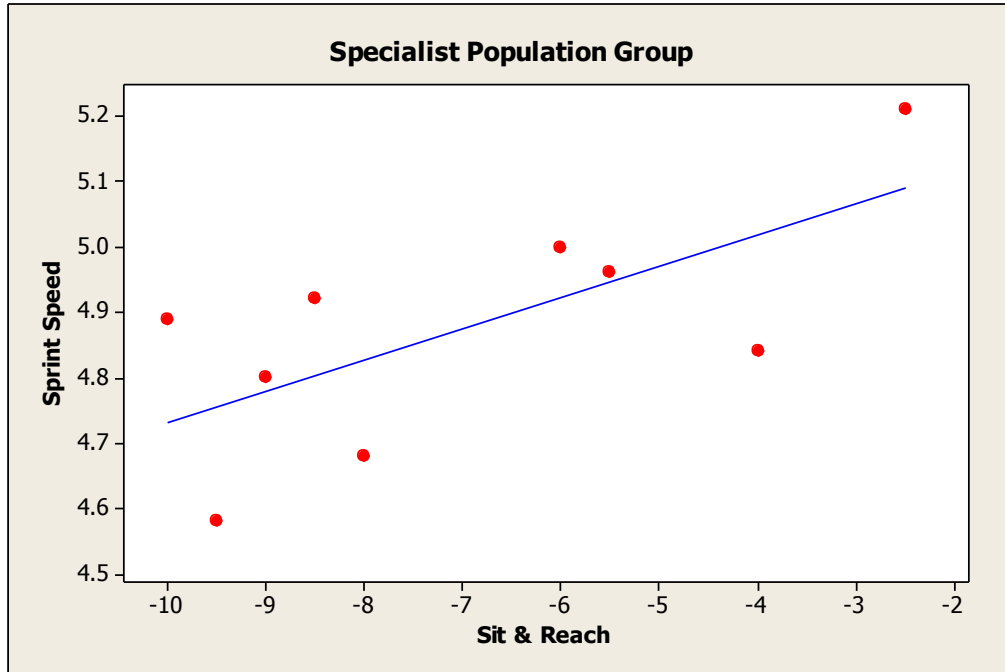


Figure 11, Scatterplot of Specialist Population