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Do isokinetic variables generated correlate to vertical jump and standing long jump measures in collegiate football athletes?

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DO ISOKINETIC VARIABLES GENERATED CORRELATE TO VERTICAL JUMP AND STANDING LONG JUMP MEASURES IN COLLEGIATE FOOTBALL ATHLETES?

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APPROVAL OF THESIS/DISSERTATION

We, the faculty supervising the work of James Russell Smothermon, affirm that the thesis, *Do Generated Isokinetic Variables Correlate to Vertical Jump and Standing Long Jump Measures in Collegiate Football Athletes?* meets the high academic standards for original scholarship and creative work established by the Masters in Athletic Training and the College of Health Sciences. This work also conforms to the editorial standards of our discipline and the Graduate College of Marshall University. With our signatures, we approve the manuscript for publication.

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ABSTRACT

In this study, a correlation between isokinetic testing of the knee and the vertical jump and single leg jump in collegiate division 1 football players was investigated. The medical records of 68 athletes were selected for this study. Correlations and two-tailed regressions were run. Data was analyzed with raw numbers as well as allometrically scaled numbers. Correlation analysis is revealed time to peak torque (TPT60) in both the right and left hamstrings at 60°/sec was significant in the vertical jump (VJ). At 180°/sec, power in the left leg (P180-LQ and P180-LH), peak torque in the left quadriceps (PT180-LQ), and left hamstring (PT180-LH) were significant for the vertical jump. Pearson *r* indicated a relationship between the variables of 60°/sec isokinetic testing. Vertical jump correlation analysis revealed that power output in the right quadriceps (P180-RQ), peak torque in the right quadriceps (PT60-RQ), right hamstring (PT60-RH), and left hamstring (PT60-VLH) at 60°/sec were significant in the standing long jump (SLJ). At 180°/sec, power in the quadriceps and hamstrings of both legs (P180-RQ, P180-LQ, P180-RH, and P180-LH) and peak torque in the quadriceps and hamstrings of both legs (PT180-RQ, PT180-LQ, PT180-RH, and PT180-LH) were significant with moderate Pearson *r* relationships for the SLJ. From these findings, correlations exist that give a better understanding of the results of the VJ and SLJ tests. The use of isokinetic testing to assist in assessing the results of on-field testing is valid.

CHAPTER I

INTRODUCTION

The National Football League Combine (NFL Combine) is a tryout held every year inviting over 300 athletes out of the top college football prospects to perform in front of professional teams (Robbins, 2010). The NFL Combine is a privilege among collegiate football players looking to take their talents to the next level. The NFL Combine includes on-field performance tests, medical and psychological testing, and selected team interviews (McGee and Burkett, 2003). All players perform a variety of physical on-field tests, psychological assessments, and medical testing to evaluate their full potential. Results from the NFL Combine help teams evaluate speed, power, strength, health, and intelligence of each athlete. Professional teams invest millions of dollars in top draft picks to improve their teams. The National Football League team owners want to know as much about their potential draft picks as they can. Results of these tests give the team owners the ability to assess each athlete of interest.

The focus for the NFL Combine evaluation process is the on-field tests. However, the medical tests provide extremely important information to team owners. Medical testing is the last piece of evaluation. Medical evaluation includes orthopedic evaluation and isokinetic testing. Isokinetic testing is performed on each athlete invited to the combine to assess underlying knee related issues (S. Konz, personal communication, March 1, 2015). The isokinetic dynamometer is a device controlling the velocity at which users move a limb allowing for evaluation of muscle power and torque generation in both concentric and eccentric contractions making it an important component of lower extremity injury assessment (Hislop & Perrine, 1967). Results from the isokinetic dynamometer become part of each NFL prospect's medical profile (S. Konz, personal communication, March 1, 2015).

While injury assessment is an important part of the evaluation process, a lack of incentive for some athletes to perform to their highest ability during isokinetic testing occurs (S. Konz, personal communication, March 1, 2015). Current research has examined the relationship between the NFL Combine, draft order (drafted and non-drafted), and the NFL Combine field assessment (Kuzmits & Adams, 2008; McGee & Burkett, 2003; Robbins, 2010; Sierer, Battaglini, Mihalik, Shields & Tomasini, 2008). There has not been a study examining draft order, performance, or on-field assessment tests and the correlation between isokinetic testing. Through field assessment tests like vertical jump and standing long jump, which are used to determine power development, athlete development, and quantify training room protocols, we can determine if a correlation is present between isokinetic and these field assessment tests. Such correlations would help scouts and team owners better gauge athlete ability.

On-field test administrators, coaches, and medical staff need another means to validate the use of isokinetic testing as well as to gather valuable information about each athlete's performance during the NFL Combine. The purpose of this study was to determine if a correlation between Cybex isokinetic dynamometer generated test results and the performance of individual athletes with two NFL Combine on-field assessment tests, specifically the Standing Long Jump (SLJ) and Vertical Jump (VJ), exists.

Operational Definitions

Below are the definitions of terms used in this research:

Isokinetic Dynamometer – a device that measures mechanical power and the output or driving torque of a rotating machine while muscles shorten and lengthen but maintaining constant torque or tension (Hislop & Perrine, 1967).

NFL Combine – a collection of the top 300 professional football prospects undergoing a series of physiological tests related to American football (Merriam-Webster's Collegiate Dictionary, 2016).

Peak Torque (PT) – the single highest point on the torque curve that evaluates the ability to produce force rapidly and can be used to determine explosive power. A prolonged time to peak torque can indicate reduced recruitment of type II fibers (Kannus, 1994).

Power (P) – work per unit of time; Power ((Power =force X distance)/time) is reported in units or watts. Power relates to the average time compared to the rate of work. Power increases with the use of increasing velocity as peak torque does during concentric contractions (Osternig, 1986).

Time to Peak Torque (TPT) –the amount of time it takes for an individual to achieve peak torque on an isokinetic device (Kannus, 1994).

Standing Long Jump (Broad Jump) – a performance test used to measure horizontally generated power.

Vertec - the most common apparatus for measuring vertical jump ability. The Vertec is the vertical jump-testing device of choice for many college and professional teams. It is of steel frame construction with horizontal vanes, which are rotated out of the way by the hand to indicate the height reached. Each vane is in 1/2 inch increments (cm increments may be available), and the height of each vane is adjustable from 6 ft. to 12 ft. (Vertec, Sports Imports, Hilliard, OH)

Vertical Jump – a performance test used to measure vertically generated power (Vertec, Sports Imports, Hilliard, OH).

Limitations

The limitations of this study include:

1. Different isokinetic test instructors administered the isokinetic tests.
2. Different strength coaches from staff administered the standing long jump.
3. Different strength coaches from staff administered the vertical jump.
4. The test records reviewed were from the 2014/2015 Marshall University football team roster.

Delimitations

The delimitations of this study include:

1. College aged (18 to 25 YO) NCAA Division I football athletes at Marshall University were used.
2. Test results gathered from the standing long jump (broad jump).
3. Test results gathered from the vertical jump test.
4. HUMAC Norm Isokinetic dynamometer tests performed at 60 °/sec on each athlete.
5. HUMAC Norm Isokinetic dynamometer tests performed at 180 °/sec on each athlete.

Assumptions

The assumptions of this study include:

1. The same strength staff members tested the athletes for all vertical and broad jump measures.
2. The results for the vertical jump and standing long jump were recorded accurately.
3. Athletes gave full and honest effort.
4. Evaluators were consistent with the use of the isokinetic dynamometer.
5. Evaluators were skilled in administering the standing long jump and vertical jump tests.

Purpose of the Study

The objective of this study was to determine if a correlation exists between Cybex isokinetic dynamometer generated test results and the performance of individual athletes with two NFL Combine on-field assessment tests, specifically the Standing Long Jump (SLJ) and Vertical Jump (VJ).

Hypothesis

Null Hypothesis

1. There is no difference between Cybex Dynamometer generated numbers with individual Standing Long Jump (SLJ) performances.
2. There is no difference between Cybex Dynamometer generated numbers with individual Vertical Jump (VJ) performances.

Alternative Hypothesis

3. There is a difference between Cybex Dynamometer generated numbers with individual Standing Long Jump (SLJ) performances.
4. There is a difference between Cybex Dynamometer generated numbers with individual Vertical Jump (VJ) performances.

CHAPTER II

LITERATURE REVIEW

On-field assessment and physiological assessment are two of the three fields used for evaluating the top athletes at the NFL Combine. The third is medical testing including orthopedic evaluation, general medical evaluation, and isokinetic testing. Isokinetic testing is performed on all athletes to assess underlying knee related issues (S. Konz, personal communication, March 1, 2015). Injury assessment of the lower extremity is a major component of the isokinetic dynamometer (Hislop & Perrine, 1967). By using the isokinetic results to correlate power, endurance, and peak torque along with the on-field tests of each athlete, NFL team owners would have another valuable piece of information regarding the draft prospect of consideration.

Isokinetic components typically investigate peak torque, time to peak torque, and power (Baker & Newton, 2008; Nosse, 1982). Peak torque represents the highest point on the torque curve and is the highest muscular force output similar to a one repetition maximum effort in weightlifting and is the most commonly used component from isokinetic testing (Davies, Heiderscheit, & Brinks, 2000). Time to peak torque is the amount of time it takes to reach the peak torque parameter (Hislop & Perrine, 1967). Power is overall how much work occurs over an amount of time (Thistle, Hislop, Moffroid, & Lowman, 1967). The velocities of 60°/sec and 300°/sec are the isokinetic test speeds used at the NFL Combine (S. Konz, personal communication, March 1, 2015). The 60°/sec setting is a slow speed in which more strength is needed by the participant to move the dynamometer arm the standard 5 repetitions (Brown, 2000). Setting the velocity at 180°/sec is a fast speed used for endurance purposes as the sets are typically 15 repetitions (Hislop & Perrine, 1967). These repetition levels are set based on research recommendations suggesting that a subject performs less than 10 repetitions to evaluate muscular power, and higher repetitions (>15) be used to evaluate muscular endurance (Davies et al., 2000). Studies indicate that peak torque is significantly increased at a slower speed (60deg/sec) when comparing 60 and 180°/sec (Brown, 2000). Also, the peak torque of a faster velocity (180deg/sec) is increased significantly at 180 and 240°/sec (Davies et al., 2000)

When testing athletes at 60°/sec, the strength/power results over a short amount of time are equivalent to an offensive and defensive lineman competing with one another during an individual play. The 180°/sec test is suited to athletes with skill sets such as wide receivers or defensive backs. The distances covered by wide receivers and defensive backs during one football play is similar to the time frame and repetitions of an endurance velocity set (180°/sec) on the isokinetic device. Certain skill positions on a football team are a combination of power and endurance. Running back skill set includes breaking long runs and running fast similar to isokinetic endurance velocity testing. However, these backs take hits and are required to block, falling more toward the power velocity tests. Linebackers tackle athletes in the open field but are also needed to cover a slot receiver down field. Therefore, the 60°/sec and 180°/sec tests are appropriate for linebackers as well. Many performance characteristics are required in the game of football. Testing each athlete at different velocities helps demonstrate their abilities more accurately to the variety of performance aspects of the game.

The Cybex HUMAC Norm Dynamometer

Isokinetics is defined as the dynamic muscular contraction occurring when a special device controls the velocity of movement at the different joints (Baltzopoulous & Brodie, 1989). The Cybex HUMAC Norm Isokinetic Dynamometer is a computer-assisted muscle testing dynamometer used to measure muscle strength and power (HUMAC Norm, 2015). The device allows for evaluation of muscles and muscle groups in an isokinetic manner. An isokinetic dynamometer challenges the muscular force development of an individual throughout the range of motion without acceleration (Hislop & Perrine, 1967). Movement is performed at a constant speed of angular motion using variable resistance provided by the user (Thistle et al., 1967). Isokinetic testing on a dynamometer produces reliable strength data when testing simple joints such as the knee (Zvijac, Toriscelli, Merrick, Papp, & Kiebzak, 2013). Isokinetic testing is used for injury evaluation, injury prevention, and return to full participation (Pincivero, Lephart, & Karunakara, 1997). The advantages of using the isokinetic dynamometer are the ability to evaluate injuries, isolate a muscle group, maximize exercise throughout the full range of motion of a limb using accommodating resistance, and present quantifiable data for peak torque, work, and power (Hislop & Perrine, 1967; Pincivero et al., 1997; Thistle et al., 1967). As for injury prevention, Ahmad, Clark, Heilman, Schoeb, Gardner, and Levine, (2006) investigated the effects of gender maturity on quadriceps to hamstring ratio and anterior cruciate ligament laxity in regards to the implementation of injury prevention, finding that males gain hamstring strength with age while females strictly gain quadriceps strength when strengthening programs are added(Ahmad et al., 2006). Hamstring strengthening needs to be implemented when strength training begins as male hamstrings mature to build quadriceps strength so upper leg strength can be balanced (Ahmad et al., 2006). Ideally, the hamstring to quadriceps ratio is balanced so when high-intensity sports are started a lower ACL injury risk exists (Ahmad et al., 2006).

Football Data Using the Cybex HUMAC Norm Dynamometer

The NFL, along with many colleges with access to the Cybex HUMAC Norm Dynamometer, uses it for testing athletes (S. Konz, personal communication, March 1, 2015). No data exists demonstrating to the public, physicians, or athletic trainers the "normal" output data for athletes performing at the highest level of competition (Zvijac et al., 2013). A side-by-side comparison of both lower extremities, or between the agonist and antagonist muscle groups, showing a discrepancy of more than 10% during isokinetic testing could indicate a predisposition to a joint or muscle injury (Sapega, 1990). However, it is uncommon for an athlete to have large discrepancies in leg size, power, and torque bilaterally (Newton et al., 2006; Nosse, 1982; Zvijac et al., 2013). Zvijac et al. (2013) found the difference between the lower extremities was only 3.85%. Quadriceps strength is highly researched in athletes and is essential when playing the sport of football. Newman, Tarpenning, and Marino (2004) found a strong correlation in their isokinetic testing of peak knee extension torque at 240°/sec and single sprint initial acceleration. The initial acceleration aspect of sprinting relates to the sport of football with the phrase heard throughout football season, "Get off the ball" (Newman et al., 2004). Sprinting requires high force generation with lower body strength and power to spring faster forward (Brechue, Mayhew, & Piper, 2010). Brechue et al. (2010) found a high correlation between isokinetic peak torque and sprint acceleration and a low correlation between increased squat strength and increased sprint speed in college football players. These data give personnel from many different aspects information needed to better athletes who sustained injuries and improve the athlete's performance through sport specific drills needed to beat their opponent. Decreasing the strength discrepancies bilaterally in the lower body not only helps the athletes perform better, but could also limit injury risk (Dos Santos Andrade et al., 2012, Östenberg, Roos, Ekdah, & Roos, 1998).

How can movements performed at a constant speed while using only a single limb compare to the level of activity these football athletes are playing? Rothstein, Lamb, and Mayhew (1987) stated, “face-validity is the lowest form of validity because it reflects whether a test appears to do what it is supposed to do.” Athlete performance testing by strength staffs is a form face validity; for example, the staff may not be skilled at administering the test or collecting the test results. The lower validity comes from multiple test administrators and their varying experience with effectively administering the test. However, criterion-related validity is strongest because the validity of numbers output by the isokinetic dynamometer and the direct numbers gathered through the performance of athletes during vertical and standing long jump are tested (Wrigley, 2000).

Knee flexors are responsible for stabilizing the knee joint because of the various tasks, running, cutting, jumping, tackling, needed during play (Cometti, Maffiuletti, Pousson, Chatard, & Maffulli, 2001). The skills evaluated during the on-field assessment of football players: vertical jumping, sprinting, and changing direction, are similar movement patterns to game skills. Knee joint stabilization is necessary for all tests performed in the combine but most importantly the 3-cone drill, pro shuttle, vertical jump, and broad jump because of the eccentric loading (Cometti et al., 2001). If the appropriate quadriceps to hamstring ratio is present before the Combine, the athlete could have an enhance performance during the on-field combine tests. In soccer, athletes who perform explosive sprinting and cutting similar to football positions, the knee flexors are more important when it comes to stabilizing the knee (Fried & Lloyd, 1992). Cometti et al. (2001) demonstrated that elite players had greater knee flexor strength, especially during eccentric movements. An investigation on hamstring weakness associated with hamstring muscle injury among Australian footballers found that six of 37 athletes tested during pre-season sustained hamstring injuries during the year (Orchard, Marsden, Lord, & Garlick, 1997). The hamstring injuries were associated with low quadriceps to hamstring ratio and low hamstring peak torque at 60°/sec (Orchard et al., 1997). The quadriceps to hamstring ratio needs to be at least 0.6 for high profile athletes to maintain healthy legs and decrease chances of lower leg injuries (Zvijac et al., 2013). Rugby league athletes demonstrated maximal leg strength during a 1 rep max squat (17%) and power (12%) as the leading factors differentiating athletes at the National Rugby League and the State Rugby League (Baker & Newton, 2008). Very similar to American Football, national rugby players need to be increased leg drive to aid in tackling and breaking tackles when trying to progress the ball forward (Baker & Newton, 2008). Cometti et al. (2001) concluded professional players differed from amateurs in terms of knee flexor muscle strength and 10-meter sprinting.

If the study can correlate the two jump tests and the isokinetic dynamometer results, will this give scouts better information regarding the athlete’s performance and the athlete’s ability? Furthermore, would teams gain a better picture of health and capabilities from the isokinetic testing by revealing the correlation of numbers generated from the dynamometer and tests performed at the Combine?

Sierer et al. (2008) questioned whether the performance tests completed on the NFL Combine athletes gives the team solid information about the athletes, correlates their success as an athlete, or if the Combine is entertainment for the fan base (Sierer et al., 2008). Studies performed on the Combine on-field tests are scattered and give few indications as to why these tests should be included as a means of predicting player success. Robbins (2012) indicated the best-correlated combine tests predicting player success were the 10-, 20-, and 40-yard sprint times because of the linear direction as maximum speed was achieved (Robbins, 2012). However, Robbins (2012) also concluded that the broad jump and the change-in-direction tests showed more correlation than the 40-yard dash and the vertical jump (Robbins, 2012). Conversely, with normalized data, the tests results are questionable to predict the NFL Draft order; however, the 18.3m shuttle better predicts draft order than the other test due to speed and change of direction aspects needed to complete the drill (Robbins, 2010). Although the 18.3m shuttle appeared to be the better predictor because of the different components needed during the drill, the normalized data provided a strong correlation between the NFL Combine invitees and the 40-yard dash and vertical jump (Robbins, 2010). The NFL combine tests are intended to measure whether an athlete possesses the unique physical attributes considered necessary to be successful in the NFL (Sierer et al., 2008).

The NFL Combine relies on agility and power drills. Athlete results are assessed by scouts and compared to other athletes in the same draft and current players in the league (Kuzmits & Adams, 2008). A strong correlation with draft success is present in the running back position when comparing their sprint times. (Kuzmits & Adams, 2008). McGee and Burkett (2003) while investigating whether the Combine was a reliable predictor of draft order, discovered that the running backs correlated very highly along with wide receivers and defensive backs. Running and jumping in a linear plane gives a small window for error for an athlete. The 40-yard sprint, standing long jump, and vertical jump occurs in a linear plane. Football skill sets do not occur in a single plane, but rather in multi-plane. Athletes must change directions effectively to carry out the duties of their position. The NFL combine uses multi-directional sprinting tests to assess the athlete's reaction time and change of direction abilities; among them is the 18.3 m shuttle. The 18.3-meter shuttle is a multi-plane activity that includes slipping, falling, and cleats getting stuck in the ground when changing direction. These factors alter the athlete's 18.3m shuttle times. From witnessing a Pro-Day, more than one opportunity to perform any on-field test is given when a fault occurs. The 40-yard dash may give the best correlation to NFL draft order, but the shuttle makes the athlete adapt and become more of an athlete than just running and jumping in the linear plane (Kuzmits and Adams, 2008; Robbins, 2010; Robbins 2012).

Biomechanics of the Vertical Jump and Standing Long Jump Tests

The vertical jump (VJ) and the standing long jump (SLJ) are simple tests. The vertical jump test measures how high an athlete can jump vertically. The vertical jump test assesses the athlete's ability to generate power, explosive strength, and how well they use that strength (Luhtanen & Komi, 1978). The athlete takes off from two feet in the vertical direction using an arm swing to generate force in order to jump as high as they can (Baker, 1996). The player swipes at the vanes of the Vertec with his hands. The vertical jump is calculated by subtracting the player's reach height while standing next to the pole flatfooted from the highest vane moved at the peak of the jump (Isaacs, 1998).

This technique requires the athlete to start in an upright position with feet parallel to each other and hip to shoulder width apart (Baker, 1996). The athlete performs a quick countermovement drop into a quarter-squat position by flexing the hips and knees into a semi-squat position while swinging their arms back to prepare for the jump (Luhtanen & Komi, 1978). After reaching their preferred depth of descent in the quarter squat, the athlete explosively extends at the knees and hips, and plantar flexes at the ankles in an effort to attain a maximal jump height (Baker, 1996). During the concentric and flight phases of the jumps, athletes are required to maintain a level head position (e.g., not looking upward at the Vertec vanes) while reaching upward with both hands simultaneously (Isaacs, 1998). The arms swing forward above the head as the athlete jumps straight up into the air while taking off with both feet simultaneously (Harman, Frykman, & Roesnstein, 1990). Arm swing influences vertical jump height and performance biomechanics (Harman, Frykman, & Roesnstein, 1990; Lees, Vanrenterghem, & De Clercq, 2004). The athlete performs a maximal jump and swats at the plastic vanes at the peak of the jump. Vertical jump height is measured as the vertical distance between the standing reach and the highest vane displaced by the subject's hand at the peak of the jump. Jump height assessed by the Vertec is determined by subtracting the standing height or reach height by the maximum jumping height or reach height using procedures such as Sargent's, Abalakov's, and Starosta's jump tests (Baechle, Earle, & National Strength & Conditioning Association, 2008). Few articles exist on determinants of success in vertical jumping. However, DeStaso, Kaminski, and Perrin (1997) found that knee extension, peak torque, and body weight ratio were significant predictors of drop vertical jump height when investigating the relationship between drop vertical jump heights and isokinetic testing.

The standing long jump is another 2-footed jump test using arm swing to accomplish the jump (Baechle et al., 2008). The standing long jump determines horizontal jump distance (Wakai & Linthorne, 2005). The standing long jump assesses horizontal power generating capabilities. The distance of a broad jump is measured from a start line where the athlete stands to the nearest body part upon landing in the horizontal direction (Ashby & Heegaard, 2002). The heel is usually the first to come into contact when landing (Wakai & Linthorne, 2005). The jumper projects his or her body from a static position. By using the countermovement of a double arm swing and double leg take off, the jumper tries to generate enough force to achieve his or her maximum horizontal distance beyond the takeoff line (Wakai & Linthorne, 2005). Arm swing has been shown to influence jump distance in the standing long jump (Ashby and Heegaard, 2002). As the jumper takes off, a forward lean of the trunk is present (Baechle et al., 2008). Through the flight phase, the jumper's legs swing underneath the body to prepare for landing (Baechle et al., 2008). Upon landing, the jumper's legs and feet are fully extended in front of the hips with a forward lean of the trunk still maintained (Wakai & Linthorne, 2005).

Isokinetic Testing in Other Sports

Isokinetic articles are focused on injury prevention. The information generated by isokinetics could give more information than possible injury related deficiencies.

Studies investigating the relationships between each NFL Combine test, predicted performance in the draft, and the difference between drafted and non-drafted athletes exist. Four studies investigated draft order and the athlete's performance in the league and none of the studies had strong overall correlations (Kuzmits & Adams, 2008; McGee & Burkett, 2003; Robbins, 2010; Robbins, 2012). When comparing drafted and non-drafted athletes, correlations were found with specific football positions (Sierer et al., 2008). The 40-yard dash, vertical jump, pro shuttle, and 3-cone drill correlated to running backs, defensive backs, and wide receivers (Sierer et al., 2008). These running backs, defensive backs, and wide receivers require the ability to sprint and quickly reach top speed, as well as jump and change direction during every play. Linebackers, fullbacks, and tight ends correlated with the results of the 3-cone drill (Sierer et al., 2008). Linebackers, fullbacks, and tight ends require quick bursts and change directions during play. These three positions, linebackers, fullbacks, and tight ends, are either backpedaling and then changing direction to run, block, jump to catch a football, or to jump over tackles.

Ability to activate the hamstring rapidly is partially important for knee joint stabilization during a powerful knee extension (Cheung, Smith, & Wong, 2012). Knee injuries are a common injury in sports like soccer and a similar sport called floorball, due to cutting, and quick sprints, and can be compared to some activities and positions in football (Delextrat, Gregory, & Cohen 2010). A low hamstring/quadriceps ratio results in greater risk of being injured in both the hamstring muscles and the knee joint (Delextrat et al., 2010). Basketball is another sport where muscle strength and vertical jump has been compared. Alemdaroglu (2000) investigated the relationship between muscle strength, anaerobic performance, agility, sprint ability, and vertical jump performance in professional basketball players, finding performances in a variety of field tests were correlated with each other; however, vertical jump and isokinetic strength were not.

Injury prevention in females is a highly researched topic. The focus is injury prevention in the lower extremity for female athletes. The hamstrings are crucial in helping the anterior cruciate ligament prevent the tibia from moving too far forward (Shephard, 2013). Quantifying muscle balance to decrease injury risk can be done through the hamstring-to-quadriceps ratio (Brown, 2000). The ratio informs the user of the level of deficiency between the opposing muscle groups. Male athletes activate the hamstrings sooner and more often than female athletes, predisposing the females to an ACL injury (Zebis, Andersen, Ellingsgaard, & Aagaard, 2011). Female muscle activity tends to be the opposite of males' muscle activity (Ahmad et al., 2006; Zebis et al., 2011).

Females exhibit a muscular imbalance between the hamstrings and quadriceps, which puts them at greater risk for ACL injury (Ahmad et al., 2006; Opar & Serpell 2014). A decreased rate of force development during initial movement in female soccer athletes can lead to decreased knee stability (Zebis et al., 2011). Female athletes frequently develop quadriceps dominance, which is an imbalance in the recruitment patterns between the quadriceps and hamstrings (Myer, Ford, & Hewett 2004). Hamstrings are typically weaker than the quadriceps in females (Zebis et al., 2011). Weaker muscles fatigue more quickly resulting in greater strength imbalances and injury risk (O'Sullivan, O'Ceallaigh, O'Connell, & Shafat, 2008). While men present a significant increase in peak torque of the hamstrings during maturity, the hamstrings control activities, like jumping, and provide joint stabilization (Dos Santos Andrade et al., 2012). A comparison of isokinetic and functional test results from female soccer players, such as vertical jump and a few others, found no significance (Östenberg et al., 1998).

We see that females when maturing are quadriceps dominant and males hamstring dominant (Zebis et al., 2011). When matured and performing at high levels, the hamstring/quadriceps ratio of at least 50% of each other characterizes a healthy knee (Dos Santos Andrade et al., 2012). Daneshjoo, Rahnama, Mokhtar, and Yusof (2013) define strength deficit as the difference in strength between muscles of the opposite extremity. The quadriceps to hamstring ratio needs to be at least 0.6 for high profile athletes to maintain healthy legs and decrease chances of lower leg injuries (Zvijac et al., 2013). According to Daneshjoo et al. (2013), a 10% deficit is considered ideal for decreasing injury risk; if the deficit is higher, it contributes to a risk of knee injuries (Daneshjoo et al., 2013).

In football, quadriceps strength is ideal for powerful movements and quick short bursts. Females run a risk of lower extremity injuries by being quadriceps dominant (Ahmad et al., 2006; Opar & Serpell 2014, Zebis et al., 2011). A muscle balance assists the athlete in generating the ideal power and endurance needed to excel in football and decrease the risk of lower leg injury in a non-contact scenario. Cybex testing gives the athletes more information than they get from athletic trainers, strength staff, or team managers when the athletes make it to the NFL level. Having a comparable quadriceps to hamstring ratio bilaterally allows the athlete to reduce the risk of a knee injury (Daneshjoo et al., 2013). The quadriceps to hamstring ratio helps quantify the work put in after an injury or setback. Cybex testing reveals possible injury, power, and work. This test is not solely used to find out what is wrong with an athlete. The isokinetic test can and will help the athlete perform to the best of their abilities.

CHAPTER III

METHODS

Methods and Materials

This study was conducted to investigate if a correlation exists between generated Cybex isokinetic dynamometer test results, 60°/sec and 180°/sec, and two functional tests, the Standing Long Jump (SLJ) and Vertical Jump (VJ).

Subjects

Medical records along with strength and conditioning testing records of 68 NCAA-I 2014/2015 football athletes from Marshall University were selected. The data were extracted from parts of standard athlete testing conducted by strength and conditioning and sports medicine staff at the University. The study received IRB approval (See Appendix A.)

Instrumentation

Isokinetic testing was performed on a Cybex HUMAC Norm Dynamometer (CSMi. Stoughton, MA.) Testing on this device was conducted at 60°/sec and 180°/sec. Vertical Jump (VJ) height was measured using a Vertec (Vertec Sports Imports, Hilliard, OH). Standing long jump (SLJ) distance was measured using a tape measure. Statistical analysis was run using IBM SPSS Statistics for Windows, Version 20.0.

Isokinetic Measurements

Each athlete was tested at the knee on the Cybex HUMAC Norm Dynamometer (CSMi, Stoughton, MA.) at speeds of 60°/sec and 180°/sec. Each athlete performed knee extension and flexion at those speeds. Specific generated numbers were taken at each speed. For power strength at 60°/sec: peak torque (PT60), power (P60), and time to peak torque (TPT60) were used. For the power endurance component at 180°/sec peak torque: peak torque (PT180), power (P180), and time to peak torque (TPT180) were used. Each leg was tested at each speed. Five repetitions were performed at 60°/sec and 15 repetitions at 180°/sec.

Combine Tests

Vertical Jump

Vertical jump is used to assess the ability to generate vertical power, explosive strength, and the ability to use strength by how high an athlete can jump (Baker, 1996). A Vertec (Vertec Sports Imports, Hilliard, OH) was used to measure vertical jump height. Standing height was measured by having the athlete stand beside the Vertec and reach up with the hand closest to the apparatus. While keeping the feet flat on the ground, the highest point the fingertips reach is marked or recorded. The athlete stands flat-footed with plastic vanes suspended above him. The athlete then jumps as high as he can, swatting at the vanes permitting the judge to determine how high that athlete jumped. They are able to jump as many times as they want as long as the next plastic piece is touched each time. Each torque and position parameter under the isokinetic measurements was correlated with each athlete's distance performed in the vertical jump.

Standing Long Jump

The standing long jump test is used to assess the ability to generate horizontal power, explosive strength, and the ability to use strength by measuring how far an athlete can jump horizontally from that standing position and helps to assess explosive power (Ashby & Heegaard, 2002). The athlete stands behind a line marked on the ground with feet slightly apart. A two-foot take-off and landing are used, with the swinging of the arms and bending of the knees to provide forward drive. The athlete attempts to jump as far as possible, landing on both feet without falling backward. The measurement is taken from take-off line to the nearest point of contact on the landing (back of the heels). Each torque and position parameter under the isokinetic measurements was correlated with each athlete's distance performed in the standing long jump.

Statistical Analysis

Data were allometrically scaled. Correlation tests (SPSS 22, IBM. Co., Armonk, NY) were run to determine the relationships between the results of the isokinetic variables and two jump test results. Multiple regression tests (SPSS 22, IBM. Co., Armonk, NY) were used to determine what isokinetic test values predict the jump test results. Significance was set at the .05. Two-tailed tests were used.

CHAPTER IV

RESULTS

The purpose of this study was to determine if a correlation between Cybex isokinetic dynamometer generated test results and the performance of individual athletes with two NFL Combine on-field assessment tests, specifically the Standing Long Jump (SLJ) and Vertical Jump (VJ) exists. Correlation tests determined relationships between the isokinetic variables and vertical jump and standing long jump test results. Multiple regression tests determined which isokinetic values predicted the vertical jump and standing long jump test results. Significance was set at the .05. Two-tailed tests were used.

Correlations between the isokinetic variables and the vertical jump (VJ), and the standing long jump (SLJ) are shown in Tables 1-4. Tables 1 and 2 show variables correlating to VJ at 60°/sec and 180°/sec. TPT in the right hamstring (RH) and left hamstring (LH) were the correlations present at 60°/sec. Power in the left quadriceps, PT in the left quad (LQ), P in the LH and PT in the LH correlated at 180°/sec. The correlations indicated a fair relationship between the variables and the vertical jump.

Table 1.

Pearson Product- Moment Correlation table of VJ to 60°/sec Isokinetic Variables

Measure	TPT60 (RH)	TPT60 (LH)
VJ	.289*	.284*
	.017	.019

Notes. N = 68. VJ = Vertical Jump, TPT60 (RH) = Time to Peak Torque at 60°/sec of the Right Hamstrings, and TPT60 (LH) = Time to Peak Torque at 60°/sec of the Right Hamstrings

$p < 0.05$* $p < 0.01$**

Table 2.

Pearson Product- Moment Correlation table of VJ to 180°/sec Isokinetic Variables

Measure	P180(LQ)	PT180(LQ)	P180(LH)	PT180(LH)
VJ	.302*	.303*	.259*	.248*
	.012	.012	.033	.041

Notes. N = 68. VJ = Vertical Jump, P180(LQ) = Power at 180°/sec of the Left Quadriceps, PT180(LQ) = Peak Torque at 180°/sec of the Left Quadriceps, P180(LH) = Power at 180°/sec of the Left Hamstrings, and PT180(LH) = Peak Torque at 180°/sec of the Left Hamstrings,

$p < 0.05$* $p < 0.01$**

Tables 3 and 4 contain the variables that correlated with SLJ at 60°/sec and 180°/sec. Power in the right quadriceps (RQ), PT of the RQ, PT of the RH and PT of the LH correlated at 60°/sec. The power of the RQ and LQ, PT of the RQ and LQ, P of the RH and LH, and PT of the RH and LH correlated at 180°/sec. The correlations indicated a fair relationship between the variables and the standing long jump.

Table 3.

Pearson Product- Moment Correlation table of SLJ to 60°/sec Isokinetic Variables

Measure	P60(RQ)	PT60(RQ)	PT60(RH)	PT60(LH)
SLJ	.*295	.360**	.286*	.278*
	.014	.003	.018	022

Notes. N = 68. SLJ = Standing Long Jump, P60(RQ) = Power at 600°/sec of the Right Quadriceps, PT60(RQ) = Peak Torque at 60°/sec of the Right Quadriceps, PT600(RH) = Peak Torque at 60°/sec of the Left Hamstrings, and PT60(LH) = Peak Torque at 60°/sec of the Left Hamstrings,
p< 0.05* *p*< 0.01**

Table 4.

Pearson Product- Moment Correlation table of SLJ to 180°/sec Isokinetic Variables

Measure	P180(RQ)	P180(LQ)	PT180(RQ)	PT180(LQ)	P180(RH)	P180(LH)	PT180(RH)	PT180(LH)
SLJ	. 475**	.409**	.573**	.482**	.417**	.413**	.402**	.421**
	.000	.001	.000	.000	. 000	. 000	. 000	. 000

Notes. N = 68. SLJ = Standing Long Jump, P180(RQ) = Power at 180°/sec of the Right Quadriceps, P180(LQ) = Power at 180°/sec of the Left Quadriceps, PT180(RQ) = Peak Torque at 180°/sec of the Right Quadriceps, PT180(RQ) = Peak Torque at 180°/sec of the Right Quadriceps, PT180(LQ) = Peak Torque at 180°/sec of the Left Quadriceps, P180(RH)= Power at 180°/sec of the Right Hamstrings, P180(LH) = Power at 180°/sec of the Left Hamstrings, PT180(RH) = Peak Torque at 180°/sec of the Left Hamstrings, and PT180(LH) = Peak Torque at 180°/sec of the Left Hamstrings,
p< 0.05* *p*< 0.01**

Forward linear regression took the factors from the correlation and determined the most important factors within the various comparisons. All isokinetic variables when body mass was included at 60°/sec were correlated ($p < .001$, $r = .713$, $r^2 = .508$) with success in the SLJ distance. All isokinetic variables when body mass was not included at 60°/sec were correlated ($p = .015$, $r = .584$, $r^2 = .341$) with success in the SLJ distance.

All isokinetic variables when body mass was included at 180°/sec were correlated ($p < .001$, $r = .726$, $r^2 = .527$) with success in the SLJ distance. All isokinetic variables without body mass at 180°/sec were correlated ($p = .004$, $r = .622$, $r^2 = .387$) with success in the SLJ distance. The most important components of SLJ at 60°/sec were time to peak torque of the right hamstring ($p = .011$), right quadriceps ($p = .029$) and peak torque of the right hamstring (p = .047). These variables make up almost half of the initial leap movement of the SLJ ($r = .465$). The most important components of SLJ at 180°/sec was only time to peak torque in the left hamstring ($p = .046$). Time to peak torque accounted for almost half of the impact of the movement ($r = .465$)

For VJ at 180°/sec, the most important components were the power of the right quadriceps ($p = .026$) and peak torque of the right quadriceps ($p = .020$). As for the weight scaled regression at 180°/sec the most important factors were the power of the right quadriceps ($p = .027$) and peak torque of the right quadriceps ($p = .020$). Right quadriceps power and the right quadriceps' peak torque accounted the greatest impact in the initial upward movement of the VJ ($r = .452$). No variables demonstrated significance at 60°/sec during the VJ.

CHAPTER V

DISCUSSION

The purpose of this study was to investigate the correlation between isokinetic variables and the vertical jump and the standing long jump in collegiate football players. Correlation analysis revealed time to peak torque (TPT60) in both the right and left hamstrings at 60°/sec was significant with a weak relationship between both variables in the vertical jump (VJ). At 180°/sec, power in the left leg (P180-LQ and P180-LH) and peak torque in the left quadriceps (PT180-LQ) and left hamstrings (PT180-LH) were significant for the vertical jump. Pearson *r* analysis indicated a moderate to weak relationship between vertical jump and 60°/sec isokinetic testing. Standing long jump correlation analysis revealed that power output in the right quadriceps (P180-RQ) and peak torque in the right quadriceps (PT60-RQ), right hamstring (PT60-RH), and left hamstring (PT60-VLH) at 60°/sec were significant with moderate to weak relationships in the standing long jump (SLJ). At 180°/sec, power in both legs (P180-RQ, P180-LQ, P180-RH, and P180-LH) and peak torque in both legs (PT180-RQ, PT180-LQ, PT180-RH, and PT180-LH) were significant with moderate relationships for the linear regression run on the standing long jump and isokinetic variables. The predictors for standing long jump at both 60°/sec and 180°/sec were all of the isokinetic variables when the data were allometrically scaled.

Vertical jump correlated with time to peak torque at 60°/sec and power and peak torque at 180°/sec. Time to peak torque (TPT) is important. Time to peak torque is the amount of time it takes for an individual to achieve the single highest measure on the torque curve (Kannus, 1994). By performing the vertical jump with a short amount of time between the squat portion of the vertical jump and the forceful knee extension action of the athlete as they leave the ground, a greater height is achieved. The quicker an athlete gets to their highest torque value indicates the ability to generate powerful muscle force. The quick amount of time used by the athletes explains this study's findings correlating vertical jump to the flexor muscle variables, the hamstrings. TPT correlated to success in the VJ at 60°/sec in the right and left hamstrings. Linthorne (2001) found that subjects achieved higher vertical jump height when a more vigorous preliminary downward phase of movement in the vertical jump was used (Harman et al., 1990).

The vertical jump test is used more than the standing long jump test to assess lower body explosive strength (Young, McLean, & Ardagna, 1995). Peak torque evaluates the ability to produce force rapidly and can be used to determine explosive power (Kannus, 1994). The level of activation and force development in the jumper's leg muscles during the vertical jump are high because the jumper has to decelerate and then reverse the downward motion (Linthorne, 2001). Deceleration of the jump is performed as the knee flexors lengthen at movement speed while the extensors muscles contract concentrically as the athlete's feet leave the ground. DeStaso, et al. (1997) found that knee extension peak torque and body weight ratio were significant predictors in drop vertical jump height.

Peak torque at 180°/sec in the left quadriceps (PT180-LQ) correlated with vertical jump height in this study. Rouis et al. (2014) saw correlations between knee extensors and vertical jump height. Comparing the Rouis study to the current one, power and peak torque at 180°/sec (P180 and PT180) of the left quadriceps correlated with the vertical jump. Alemdaroglu (2012) found no significant correlation between isokinetic strength and field tests, which may have been due to a small subject pool. Cronin and Hansen, (2005) also found no correlation when investigating strength and power predictors of speed in 26 rugby players. The major difference between the previously mentioned two studies and the current study is the number of subjects. This study used a total of 68 athletes, which gives more significant power to the results. The larger number of participants in the study has greater power indicating greater validity. Cronin and Hansen, (2005) did find correlations between squat jump height, countermovement jump height and sprint times of the fastest athlete group tested (Cronin & Hansen, 2005). Training of the hip flexor muscles enhances vertical jump performance in the absence of the changes to the explosive muscle function of the takeoff legs (Young, et al., 1995).

Although the correlations were limited through the isokinetic variables, linear regression indicated the variables providing the greatest impact on standing long jump performance. No relationship existed between the variables when linear regression analysis was run for vertical jump performance and isokinetic testing results. The lack of correlation between the isokinetic numbers and the vertical jump could be the testing of the single muscle groups (quadriceps and hamstrings) at the knee. The vertical jump uses more hip musculature, anterior tibialis and gastrocnemius of the lower leg in order to perform the test at maximum ability (Leard et al., 2007). Not to mention, the arm coordination and timing needed by the athlete when swinging the arms upward to swipe and hit the Vertec vanes at the peak of the vertical jump (Leard et al., 2007).

Standing long jump correlated with many variables at 60°/sec and 180°/sec. Reilly, Atkinson, and Coldwells (1991) found that standing broad jump performance was significantly correlated with peak torque. From our study, peak torque correlated at both speeds in the standing long jump test. The specificity of muscle activity at higher speeds (300°/sec) also strongly correlated with jump performance (Reilly et al., 1991). Again, from the present study, significance in the amount of peak torque that both legs generated at 180°/sec existed and a moderate correlation to standing long jump performance was demonstrated.

The stepwise linear regression showed a stronger relationship with the standing long jump at both velocities and a greater number of variables impacting the results than the vertical jump. The standing long jump is more of a natural jump and is present in many games and sports (Castro-Pinero et al., 2010). Hoffman, Epstein, Einbinder and Weinstein (2000) found that differences in the power produced by the legs acting simultaneously or successively, or when upper-body musculature is active or passive, may have a profound influence on power expression.

Absolute strength is important in football. Assessing absolute strength in football occurs every year. However, absolute strength is confounded by several variables, which include gender, maturity level, history of resistance training, and body size (Jacobson, Thompson, Conchola, & Glass, 2013). Studies and experience show that those with greater body mass are stronger than those with less; and that as size increases, the strength of the relationship between strength and body size increases (Jacobson et al., 2013). For this specific study, joint torque and power were assessed of single muscle groups instead of absolute strength. Nonetheless, joint torque should increase at a higher rate with respect to body size than muscle force (Jaric, Mirkov, & Markovic, 2005)

Normal generated isokinetic variables give little to no correlation due to the various body masses of the athletes used in this current study. Common sense tells us that heavier massed athletes are stronger than lighter athletes. Comparing an offensive lineman to a defensive back is not realistic when discussing overall relative absolute strength. The distinct and broad range of body size in American football lends itself to the need for normalization of performance to better compare strength and power parameters based on established norms (Jacobson et al., 2013). The use of allometric scaling gives us the opportunity to compare varying sized athletes. Allometry is the relationship between size and physiology and is calculated by implying that two individuals of different sizes with common dimensions will have similar ratio values (Jacobson et al., 2013).

The findings of the allometric scaled data used in conjunction with isokinetic testing open up more research questions. Jaric et al. (2005) suggested that using an allometric normalization method could allow for better means by which to measure and compare current performance variables and the progress of training or rehabilitation. Weir, Housh, Johnson, Housh and Ebersole (1999) studied allometric scaling of isokinetic peak torque in high school wrestlers and found a correlation between all the dependent variables (fat-free mass, age, and fat-free mass versus age interaction) and peak torque. After the correlation, a regression was run comparing the different age groups that were used within the high school wrestling team indicating differences among all the age groups. Also, Brechue et al. (2010) found a significant relationship when body mass was correlated with lower body strength during initial acceleration and velocity during lower body explosive exercise.

Summary

The results of this study found significance and indicated weak to moderate correlations exist between isokinetic variables at 60°/sec and 180°/sec and collegiate football players' ability to perform the standing long jump and vertical jump. The results of this study indicate that the isokinetic variables of power, peak torque, and time to peak torque in the muscles surrounding the knee predict success in the vertical jump and standing long jump. We also saw that allometric scaling is useful for the sport of football with the different sized athletes. A few limitations in this study exist that may have altered findings including the number of athletes tested per position, various isokinetic testers, and various strength staff members administering the vertical jump and standing long jump tests.

Future Research

For future research, a few things need consideration to improve the methods and gain more knowledge on this subject matter. More subjects and greater distribution of position players needs to be used to help to decrease the variance in the participant pool. Isokinetic testing of the hip and ankle, as well as the knee, should be conducted and then compared to the field tests. The addition of the isokinetic hip and ankle testing might isolate joint and musculature involvement better to be compared to the field tests. Also, the use of allometric scaling comparing each position to itself instead of the participant pool may give position specific information. Different isokinetic dynamometer velocities, such as 240°/sec or 300°/sec, could provide a different perspective, as well. Also, by administering the isokinetic testing and jump tests with the same tester, more consistent and reliable results would be achieved. The remaining field assessment tests, 40-yard sprint and 18.3m shuttle, need correlation with isokinetic tests. In all, by using the same methods as in this study and adding the things listed above, more questions could be answered.

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APPENDIX A: IRB Letter of Approval

MARSHALL UNIVERSITY

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Office of Research Integrity
Institutional Review Board
401 11th St., Suite 1300
Huntington, WV 25701

FWA 00002704

IRB1 #00002205
IRB2 #00003206

March 9, 2015

Suzane Konz, PhD
Kinesiology Department, COHP

RE: IRBNet ID# 721743-1
At: Marshall University Institutional Review Board #1 (Medical)

Dear Dr. Konz:

Protocol Title:	[721743-1] A comparison of isokinetic variables and standing long jump and vertical jump power output in college athletes
Expiration Date:	March 9, 2016
Site Location:	MU
Submission Type:	New Project APPROVED
Review Type:	Exempt Review

In accordance with 45CFR46.101(b)(4), the above study was granted Exempted approval today by the Marshall University Institutional Review Board #1 (Medical) Chair for the period of 12 months. The approval will expire March 9, 2016. A continuing review request for this study must be submitted no later than 30 days prior to the expiration date.

If you have any questions, please contact the Marshall University Institutional Review Board #1 (Medical) Coordinator Bruce Day, ThD, CIP at 304 696-4303 or day50@marshall.edu. Please include your study title and reference number in all correspondence with this office.