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Correlation Between Time to Peak Torque and Peak Torque to Vertical Jump in College Age Athletes

Craig Adam Kowalski
craig_14225@msn.com

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By
Craig Adam Kowalski, BA, ATC

Approved by
Dan Martin Ed.D Committee Chair Person
Steven Banks Ed.D
Jeff Chandler Ph.D
Marshall University
Huntington, West Virginia

Abstract

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to vertical jump in college age athletes.

Craig Adam Kowalski, BA, ATC.

The vertical jump is an essential part of athletics to gain an advantage over the opponent. Isokinetic testing provides quantitative data to determine power and how fast power or peak torque is achieved.

In this study, after 20 NCAA Div. II athletes were measured for three trials of maximal vertical jump, they completed an isokinetic test of knee extension at speeds of 60, 180, and 300˚/sec.

The results showed a significant correlation ($p<0.05$) between peak torque at a speed of 300˚/sec and vertical jump $p<=0.019$.

As a result of this study it was found that the vertical jump test is a test of muscle power generated by the quadriceps muscle group, and relates to peak torque values documented by isokinetic testing at 300˚/sec of knee extension.

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CHAPTER I

Introduction:

A common movement in sport is the vertical jump. The purpose of the vertical jump can vary by the sport. The vertical jump has long been used as a measure of power. The performer must apply force to the body's mass to accelerate it as much as possible while it is still in contact with the ground as stated by Kreighbaum, and Barthels (1996). The vertical jump could be executed in a rebound in basketball, spiking a volleyball, or catching a touchdown pass. Each of these examples relates to each other because of the muscles used, the all or none principle, as well as the stretch shorten cycle. This movement primarily involves the lower body as power is produced by the quadriceps group, ankle plantarflexors, and hip extensor muscles.

Sport specific training is recommended for every type of activity. Muscle strength training for speed, power, and coordination are goals of strength and conditioning programs. The vertical jump is widely utilized as a test of athletic ability, and lower body power. An isokinetic dynamometer is used in the clinical setting to collect information regarding absolute power, relative power (in relation to body weight), and the rate of muscular fatigue. This device is also used as a tool to help determine when an athlete can return to play following injury, by providing information to compare an injured limb to the contra-lateral side. Isokinetic testing is not for all athletes. For example a major league baseball pitcher can not fully test their arm strength using a dynamometer because the speeds can not be matched up to his sport specific demands. Isokinetic machines are expensive and are not found in most clinics and colleges. The dynamometer is also hard to use when a clinician in not properly trained or had the practice at setting up a subject, and the data is hard to interpret if not taught to understand and use the data.

The isokinetic test and the vertical jump test can be used together because of the assessment of muscle power obtained from both tests. Vertical jump is a test of leg power and to achieve maximal height power is derived very quickly, and the isokinetic machine tests leg power combined with a component of time. Also, with this data better training programs can be developed that is sport specific and meets the goals of gaining power, strength, and speed.

Purpose of the study:

The purpose of this study was to determine if vertical jump related to peak torque or if vertical jump height related to peak torque.

Significance of the study:

In sporting events a key component is to have the ability to jump vertically higher then the opponent. The athlete should be able to jump at or near their genetic maximal potential. This study is significant because there is a correlation between vertical jump and the maximum amount of power an individual can create at the knee joint. Using the data from this study a development of a concept to train an athlete to jump higher by training them using faster speed activities may be found. The stretch shorten cycle will also be a factor in this study by having each subject attempt a vertical jump with a quick countermovement followed by the vertical component of the jump. Using the dynamometer the knee will start in a flexed position which will allow the quadriceps to be in a slightly stretched position at the start of the muscle contraction. Isokinetic testing provides an effective way to attain objective measures which are valid, reliable, and reproducible.

The research evaluated both male and female subjects that participate in various sports at the NCAA Division II level. The test evaluated dominant leg strength versus vertical jump score.

Hypotheses:

The study tested the following null hypotheses.

1. There is no significant relationship between vertical jump height and time to peak torque.
2. There is no significant relationship between vertical jump and peak torque.

Definitions:

Isokinetics: Isokinetics, or accommodating resistance, is a form of exercise where a person provides a maximum muscle contraction against a resistance or lever arm, (isokinetic dynamometer) at a fixed speed through a given range of motion. This type of muscle action can be done either concentrically or eccentrically at the given joint.

Vertical Jump: The vertical velocity of the body's center of gravity at takeoff determines how high the center of gravity will travel unless acted on by an external force.

Peak Torque: Is the greatest amount of force produced by a muscle. This can be determined within each repetition or the entire set. Peak torque indicated the muscle's maximum capability of developing force. This is also equivalent to a 1-repition maximum isotonic strength test. Peak torque is an absolute value.

Time to Peak Torque: A measure of time from the start of muscular contraction to the point of the highest torque development. This value is an indicator of the muscles functional ability to produce torque quickly. The value is taken from the peak torque repetition.

Length Tension Relationship: The force of muscle contraction can be influenced by the length of the muscle at the time it was stimulated to contract. The length tension relationship states that the contractile tension the muscle is able to produce increases with the length of the muscle and is maximum when the muscle is at its resting length. This is the length where the greatest number of actin and myosin cross bridges exist. The contractile tension produced decreases as the muscle becomes shorter, or as it is stretched beyond resting length. Greater total tension is produced when the muscle is in an elongated or stretched position. The increased tension occurring with stretch is not solely contractile muscle tension but is due to the contribution of the elastic component in the tissues.

Stretch Shortening Cycle: During muscle contraction the musculotendonous junction produces a force on the bones. The force produced can be increased if the muscle is stretched to cause an eccentric tension prior to a concentric contraction.

Muscle Fiber Type: Type 1 (Slow Twitch) develop force slowly and have long twitch time. Generally fatigue resistant, highly aerobic, slow speed for force development, and low anaerobic power. Type 1 fibers are recruited first in a muscle contraction. Type II (Fast Twitch) develops force rapidly for a short period of time. High fatigability, low aerobic power, high anaerobic power, and rapid force production.

Assumptions:

In this study each subject were asked questions about their health history. Testing was not done on an individual that has had a knee injury in the past 3 months. Based on the response of the subject it was assumed that they are qualified for the study. Also a subject should not have had any lower extremity surgery or knee surgery on a ligament or meniscus in the last year. It will also be assumed the subjects will not be taking any performance enhancing drugs, and are in good physical condition and are physically active in the off season to maintain fitness. It will also be assumed that with instruction and practice repetitions on the dynamometer that the subjects felt comfortable and gave their full effort to the test.

Limitations of the study:

The limitations of this study were,

1. The limited sample size; subjects were selected from one location and are all NCAA Division II athletes.
2. This study will also only test the subjects one time and use the data to make a correlation. This is not an experimental design that we are testing against a control, experimental, and placebo group.
3. Due to time restraints finding subjects that would like to participate in the study was difficult and limited the number of possible candidates.
4. Subjects that had been in their post-season and may have fallen out of their level of fitness that may have limited their performance during the isokinetic test.
5. Also athletes could have been sick or physically run down as a result the time of year that the data was collected mostly winter and early spring.
6. Data can be altered due to some high coefficient of variance because the Biodex™ is not bolted to the floor and there is excessive rocking of the machine while testing.
7. The subjects reported that they have never been on an isokinetic machine and could have been apprehensive.
8. Only knee extension and flexion were tested. A vertical jump is a movement that occurs at many joints especially the ankle and hip.
9. Isokinetic machines are not sport specific.
10. Isokinetic testing is an open kinetic chain activity and vertical jump is a closed kinetic chain activity.

CHAPTER II

Review of the Literature

Anatomy of the Knee:

Gray (1985) defined movement that occurs at the knee joint as movements of flexion, extension, and slight internal and external rotation. The movement of flexion and extension does not, however, take place in a simple hinge-like manner. Through a series of complicated movements, consisting of a certain amount of gliding, and rotation, so that the same part of one articular surface is not always applied to the same part of the other articular surface and the axis of motion is not a fixed one. This rotation is due to the greater length of the medial condyle, and the fact that the anterior portion of its articular surface is inclined obliquely outward. Toward the end of extension, just before complete extension is achieved the tibia glides obliquely upward and outward and continues to roll externally over the oblique surface of the medial condyle, and the leg is therefore rotated externally. In flexion of the joint the converse of these movements takes place. The tibia glides backward round the end of the femur, and at the commencement of the movement the tibia is directly downward and inward along the oblique curve of the inner condyle, thus causing an inward rotation to the leg.

A further description of knee anatomy by Starkey and Ryan (2002) defines the patella as a sesamoid bone located in the patellar tendon that improves the mechanical function of the quadriceps when extending the knee, dissipates forces received from knee extension, and protects the anterior portion of the knee.

Surrounding the circumference of the knee joint is a fibrous joint capsule. Along the medial, anterior, and lateral aspects of the joint, the capsule arises superior to the femoral condyles and fixates distal to the tibial condyles. Posteriorly the capsule attaches to the posterior margins of the femoral condyles above the joint line, and inferiorly, to the posterior tibial condyle. The strength of the capsule is reinforced by the collateral ligaments medially and laterally, the retinaculum medially and laterally, the oblique popliteal ligaments and arcuate ligaments posteriorly, and the patellar tendon anteriorly.

Soft Tissue Support:

The medial collateral ligament (MCL) supports the medial aspect of the knee. The MCL is formed by two layers; the deep layer is a thickening of the joint capsule having an attachment to the medial meniscus. Separated from the deep layer by a bursae, the superficial layer arises from a broad band just below the adductor tubercle to insert on a relatively narrow site seven to ten centimeters below the joint line. As a unit the two layers of the MCL are taut in complete extension. The MCL serves primarily to protect the knee against valgus forces while also providing secondary restraint against external rotation of the tibia and anterior translation of the tibia on the femur, especially in the absence of an intact anterior cruciate ligament Starkey (2002).

The lateral collateral ligament (LCL) has no attachment to the joint capsule or meniscus. This prominent, cordlike structure arises from the lateral femoral condyle, sharing a common site of origin with the lateral joint capsule, and inserts off the proximal aspect of the fibular head. The LCL is the primary restraint against varus forces when the knee is between full extension and 30 degrees of flexion. This structure also provides secondary restraint against external rotation of the tibia on the femur Starkey (2002).

The anterior cruciate ligament (ACL) arises from the anteromedial intercondylar tubercle of the tibial and travels posteriorly and laterally to insert on the medial wall of the lateral femoral condyle. The ACL serves as a static stabilizer against: 1) anterior translation of the tibia on the femur, 2) internal rotation of the tibia on the femur, 3) external rotation of the tibia on the femur, and 4) hyperextension of the tibia. Throughout the midrange of motion, the amount of stress placed on the ACL is minimized when the tibia remains in the neutral positions. In the terminal fifteen degrees of extension, internally rotating the tibia greatly increases the strain placed on the ACL, whereas externally rotating the tibia markedly reduces the strain. Both valgus and varus stresses increase the strain placed on the ACL throughout the entire range of motion. Shorter and stronger then the ACL is the PCL the posterior cruciate ligament. The PCL arises from the posterior aspect of the tibia approximately one centimeter distal to the joint surface and takes a superior and anterior course passing medially to the ACL to attach to the lateral portion of the femur's medial condyle. The PCL is described as a primary

stabilizer of the knee. The primary restraint against posterior displacement of the tibia on the femur, the PCL's posterior fibers are taut when the knee is fully extended and the anterior fibers when the knee is fully flexed. During the screw home mechanism the PCL and ACL wind upon each other in flexion and unwind in extension Starkey (2002).

The arcuate ligament complex formed by the oblique popliteal ligament and the arcuate popliteal ligament, the arcuate ligament complex provides support to the posterior joint capsule. The oblique popliteal ligament, and expansion of the semimembranosus tendon, arise off the tibia's medial condyle and travels superiorly and laterally to attach on the middle portion of the posterior joint capsule. Arising from the fibular head, the arcuate ligament passes over the popliteus muscle, where it diverges to insert on the intercondylar area of the tibia and the posterior aspect of the femur's lateral epicondyle Stakey (2002).

The menisci are fibrocartilaginous structures designed to: 1) deepen the articulation and fill the gaps that normally occur during the knee's articulation, 2) provide lubrication for the articulating surfaces, 3) provide shock absorption, and 4) increase the stability of the joint. The medial meniscus resembles a half-crescent, or C, that is wider posteriorly then anteriorly. The lateral meniscus is more circular in shape. Both menisci are attached at their periphery to the tibia via the coronary lilgament. The anterior horns of each meniscus are joined together by the transverse ligament and are connected to the patellar tendon via patellomeniscal ligaments. The lateral meniscus is smaller and more mobile the medial meniscus. The lateral meniscus also attaches to the ACL, to the femur via the ligament of Wrisberg, and to the popliteus muscle via the joint capsule and coronary ligament. Each meniscus may be divided into a vascular zone, which runs contiguously with its peripheral attachment to the coronary ligament and joint capsule, and an avascular zone formed by the inner portion of the meniscus Starkey (2002).

Muscles of the knee:

The quadriceps muscles are comprised of the vastus lateralis, vastus intermedius, vastus medialis, and rectus femoris each muscle has a common attachment to the tibial tuberosity via the patellar tendon. As a group, the quadriceps femoris extends the knee, while the rectus femoris also serves as a hip flexor, especially when the knee is flexed.

The posterior muscles, the semitendinosus, semimembranosus, and biceps femoris, are collectively known as the hamstring group and act as a unit to flex the knee and extend the hip. The biceps femoris serves to externally rotate the tibia while the semimembranosus and semitendinosus act to internally rotate the tibia Hollinshead & Rosse (1985).

Muscles of the Knee, Ankle, and Hip

Knee Extensors	**Knee Flexors**	**Ankle Plantarflexors**	**Hip Extensors**
Rectus Femoris	Biceps Femoris	Gastrocnemius	Biceps Femoris
Vastus Medialis	Semimembranosus	Soleus	Semimembranosus
Vastus Lateralis	Semitendinosus	Peroneus Longus	Semitendinosus
Vastus Intermedius	Popliteus	Peroneus Brevis	Gluteus Medius
	Sartorius	Tibialis Posterior	Gluteus Maximus
	Gracilis		

Neuroanatomy:

As described by Dye and Vaupel (2000) neuroanatomy of the knee is comprised of the femoral nerve, tibial nerve, and common peroneal nerve are the primary nerves that innervate the muscles that move the knee. The femoral nerve divides into anterior and posterior divisions approximately 4 cm distal to the inguinal ligament. The anterior division gives off two cutaneous branches and two muscular branches. The posterior division gives off one cutaneous branch (saphenous nerve) and all of the muscular brances to the quadriceps muscles.

The tibial nerve arises in the lower one-third of the posterior thigh, passes through the popliteal fossa, and enters the posterior compartment beneath the soleus muscle. It supplies the gastrocnemius, soleus, popliteus, semimembranosus, semitendinosus, and long head of the biceps femoris. The common peroneal nerve enters the popliteal fossa on the lateral side of the tibial nerve and follows closely the medial border of the biceps femoris muscle. It then leaves the fossa by crossing superficially the lateral head of the gastronemius, passes behind the head of the fibula, and then crosses the fibular neck before piercing the peroneus longus muscle. The muscle branch to the short head of the biceps femoris is given off proximally in the popliteal fossa.

The peroneal nerve is vulnerable to injury because it lies just under the skin at the fibular neck.

Principles of Isokinetics:

There have been several studies that evaluated isokinetic testing to determine muscle power because of the numerical data that can be obtained from such a test. There are also numerous studies using isokinetics and developing normative data for return to play criteria and general strength measures.

Biodex described the principles behind isokinetic exercise and testing as the lever arm moves at a pre-set fixed speed allowing for accommodating resistance to the effort the subject applies. Resistance is equal to the effort applied by the subject. The lever arm speed will then measure torque produced by the patient through the range of motion. Because of the accommodating resistance the muscle is loaded throughout the range of motion the patient's resistance is then equal to the effort they apply regardless of the length tension curve which varies with isotonic loading or pain. The lower preset speed the more torque can be produced concentrically. By increasing the preset speed torque production will decrease. Strength deficits are more pronounced at the slower speeds. This is due to the fact that the muscles have enough time to recruit motor units and generate torque. With higher speeds, there will be the lever arm decelerating into the end stop causing a spike in the torque curve at the end ROM. This may appear as a peak torque value and can be eliminated by windowing data. Isokinetic testing can be evaluated as being reliable or valid by looking at the coefficient of variance. This is defined as the standard deviation of the torque data divided by the mean average torque. A large coefficient of variance can be attributed to pain, lack of maximal effort, apprehension due to unfamiliarity of the movements, and or poor instruction given by the tester. Acceptable coefficient of variance can be ≤ 15%. These would include large muscle groups of the knee, shoulder, back, and elbow Biodex (2001).

The Biodex System II Dynamometer™ (Biodex Medical Systems, Shirly, NY) has been tested for validity and reliability and it was found that human subjects react similarly from test to retest sessions on the Biodex system II™.

Within the limits of the study done, these results indicate that the Biodex System II™ is a reliable clinical tool for assessing peak torque, total work, and average power data Brown, Whitehurst, Bryant, and Buchalter (1993).

When conducting isokinetic testing of the knee the subject has limits placed on their full range of motion. Greenwood & Kleiner (1997) tested subjects within a limited range of motion and a range of motion free from limits placed to the joint. It was found that there was no significant difference between subjects that had a pre-set range of motion and those that had an unrestricted range of motion of the knee when evaluating peak torque produced.

When Hislop and Perrine introduced isokinetic testing to the medical field in 1967 there has been a growing interest in conducting research about isokinetic testing. Recent advances in technology have led to the development of isokinetic dynamometry that is designed to measure concentric torque and work at angular velocities greater then 300˚/sec. Since various sporting activities occur at velocities that range from an estimated 700-9,000˚/sec. During the acceleration phase of throwing a ball the shoulder internal rotators can reach an angular velocity of close to 7,000 degrees per second and has been shown to be as high as 9,000 degrees per second Chant (2003). It has been postulated that as speeds of concentric isokinetic contraction increases, the hamstring muscles become the major dynamic stabilizer of the knee. Ghena, Kurth, Thomas, and Mayhew (1991) reported that when testing quadriceps torque as speed increased torque production decreased. Concentric isokinetic loading of the quadriceps musculature demonstrated decreasing torque production as the angular velocity increased. This finding is believed to be affected by muscle composition, time for motor fiber activation, activity level, and gender. Also in this the quadriceps produced torques at 300 and 450˚/sec, which were 56 and 46 percent, of the torque generated at 60˚/sec. Many movements in athletics rely on eccentric contraction of muscle to control motion. The recent development in dynamometry to record eccentric isokinetic torques has produced conflicting research results. In this study there was no significant difference between the quadriceps and hamstring torques measured eccentrically at 60 and 120˚/sec.

In a study done by Paasuke, Ereline, Gapeyeva (2001) the researchers used knee extension strength and vertical jumping performance in Nordic combined athletes by using isometric and isokinetic tests in relation to vertical jump height to determine a level of power for Nordic athletes. For the measurement of maximal and explosive muscle strength of the lower extremities in athletes isometric or isokinetic dynamometry has been frequently used, which gives information about maximal voluntary force generating capacity of various muscle groups and jumping tests on force platforms, which provides information about the dynamic explosive force production capacity of the leg extensor muscles by measuring the jumping height. The most common measurement of vertical jumping performance is jumping height. The vertical jumping height depends on the physiological process which takes place in the muscular and nervous systems as well as on biomechanical factors. In the study Paasuke, Ereline, and Gapeyeva (2001) also found that the increased recruitment of motor units in the early part of voluntary contraction has been associated with neural adaptation. The increased isokinetic knee extension peak torque during explosive type strength (power) training as an indicator of special neuromuscular adaptation had been related to the training loads.

A static jump consists of a concentric action of the leg extensor muscles while a countermovement jump consists of an eccentric-concentric muscle action, called the stretch shorten cycle. The stretch shortening cycle is a re-utilization of stored elastic energy. It has been proven that a counter movement jump allows subjects to attain greater joint movement, especially at the hip joints.

Thomas, Fiatarone, and Fielding (1996) found the relationship between the vertical jump height and double leg press was strong because power development during the vertical jump depends on the quantity and efficiency of force production at the hip, knee, and ankle joints. This study extends these findings to associate vertical jumping ability with maximal power development during leg extension. In addition it further supports the utility of the vertical jump test as a suitable field measure for evaluating leg power.

Isokinetic imitation of the stretch-shortening cycle can be a useful progression in the functional rehabilitation for an athlete who may utilize the stretch-shortening cycle in their respective sporting activity. It would allow athletes to combine both concentric and eccentric muscle actions into a more functional activity, rather than having to work them separately. Isokinetic imitation of the stretch-shortening cycle may be an important quantitative tool to use in the rehabilitation and conditioning of athletes was found by DeStaso, Kaminski, and Perrin (1997).

Nagano and Gerritsen (2001) found in their study that there are three major points of emphasis when training to enhance jumping. The first is to exercise to increase maximum muscle forces (cross-sectional area) by going through heavily loaded weight training using free weights and or weight machines. Next, exercises should focus mostly on the muscles around the knee joints, and to include exercises that incorporate jumping movements that allow the athlete to learn how to use the strengthened muscles.

Isokinetic machines have their advantages and disadvantages. Kisner and Colby (2002) reported the advantages and disadvantages to this type of exercise.

Advantages of isokinetic testing are:

1. Isokinetic equipment can provide maximum resistance at all points in the range of motion as a muscle contracts.
2. Both high-speed and low-speed training can be done safely and effectively.
3. The equipment accommodates for a painful arc of motion.
4. As a patient fatigues, exercise can still continue.
5. Concentric and eccentric work in the same muscle group can be performed repetitively.
6. Reciprocal exercise against resistance can be performed, allowing one muscle group to rest while its antagonist contracts. This minimizes muscle ischemia.
7. Computer based visual or auditory cues provide feedback to the patient so that sub-maximal to maximal muscle work can be performed more consistently.

Disadvantages of isokinetic testing are:

1. The equipment is large and expensive
2. Set-up time and assistance from personnel are necessary if a patient is to exercise multiple muscle groups.
3. The equipment cannot be used for a home exercise program.
4. Most units provide only open-chain resistance.
5. Isokinetic machines are not sport specific and functional.
6. Isokinetic machines have a limited carry over effect to actual sport, where there is a set resistance and speed.

Vertical Jump

The most common measurement of vertical jumping performance is jumping height Kreighbaum et al. (1996). The vertical jumping height depends on the physiological processes which take place in the muscular and nervous systems as well as on biomechanical factors.

During a vertical jump the goal of the subject is to leave the ground and reach their genetic limit of maximal height. Kreighbaum et al. (1996) defines the vertical jump as the vertical velocity of the body's center of gravity at takeoff determines how high the center of gravity will travel unless acted on by an external force nothing can be done to change the determined path of the center of gravity after the body is in air. The vertical take off velocity of a human body is usually relatively small and because the body is traveling through air in a fairly streamlined position, the influence of air resistance is minimal. If horizontal displacement is unnecessary then 100% of the resultant projection velocity should be in the vertical direction. The height of the center of gravity of the body relative to the ground should be maximized before takeoff. In anatomical position the center of gravity will be in the pelvic region. The center of gravity can be raised by moving the arms over head. Raising the center of gravity within the body while still supported also raises the center of gravity relative to the ground. By leaving the ground with both arms flexed overhead may move the center of gravity a few centimeters higher as it leaves the ground therefore also when it gets to the vertical peak. The technique of raising the segments to raise the center of gravity must be done prior to takeoff.

Alexander (1992) reported that the center of gravity is about 1.0 meters from the ground or 50 millimeters above the hips. As the subject bends their knees and raises onto their toes a the end of the take-off phase they do not leave the floor until the center of gravity reaches approximately 1.05 meters. Thus the subject will accelerate their center of gravity over a distance of about .4 meters, from .65 to 1.05 meters from the ground.

In order to complete a vertical jump the body must receive an external force and that external force is the ground reaction force (GRF) that the jumper creates by pushing against the ground. According to Newton's laws of action-reaction whenever two bodies or objects come into contact with each other or exert gravitational force on one another, they apply an equal amount of force on each other, but in the opposite direction. In the case of the vertical jump as the subject pushes off the ground producing a force down on the earth, the earth then supplies an equal and opposite force back on the subject to get them off the ground Knight (2002). The pushing pattern is the sequential application of segmental power that is used to produce a greater GRF on the body. The GFR is an external force applied to the feet and as other forces has a line of action. The line of action ideally should pass through the body's center of gravity.

The jumping motion consists of a sequential application of musculotendinous power from the hip proximally through the ankle distally. The initial upward motion of the sequence is flexion of the arms at the shoulder joints. During their upward action acceleration, the arms exert a downward reaction force on the segments below them. This squeezing of the lower segments enhances the negative work or eccentric action of the antigravity muscles. Sometime during the midst of their flexion, the arms begin to decelerate, this deceleration un-weights the lower segments. During the deceleration phase of the arms, the optimum time to begin extension of the trunk about the hip joints begins. This allows the performer to use the elastic recoil of the lower segments. The extensor muscles exert tension during their joints' flexions; they are functioning with eccentric tension and therefore can use the elastic recoil action.

There are two important advantages to the segmental nature of the jumping action. First, the lower segments are allowed to extend through a greater range of motion. Second, the extensor muscles of the lower segments are stretched to a greater extent before their contractions. The stretch reflex is evoked, which enhances the muscle's contractile force, and it allows a greater use of the series elastic component of the tissues around the joint. Merely increasing the range of motion during the flexion does not necessarily produce a greater extension force. The extensor muscles must be tensed during the joint flexion phase for the recoil of the elastic component to contribute to the extension of the joints. The momentum of the arms is conserved within the entire system; therefore, as these segments decelerate, an increase occurs in the velocity of the body's center of gravity upward. Consequently, the force resulting from the final extension of the supporting knee and ankle joints is used to further increase the momentum of the already upward traveling center of gravity Kreighbaum et al. (1996).

Muscle Function

Tension characteristics of the muscle can be broken down into a few different ways. As McArdle, Katch, and Katch (1996) describe that the force of muscle action is varied from slight to maximal in two ways called the gradation of force, first, increasing the number of motor units recruited for the activity, and increasing their frequency of discharge. The force generated is considerable if all of a muscle's motor units are activated. Also, if repetitive stimuli reach a muscle before it has relaxed; there is a further increase in the total tension produced. By blending these two factors, the recruitment of motor units and the rate of their firing, optimal patterns of neural discharge permit a wide variety of graded muscle actions-from delicate touch required in eye surgery to the maximal effort in throwing a baseball from center field to home plate.

Few motor units are activated for low-force muscle actions, whereas higher force progressively enlists more motor units. The process of adding more motor units to increase muscle force is known as motor unit recruitment. As muscle force increases, motorneurons with progressively larger axons are recruited. This is known as the size principle, which provides an anatomic basis for the orderly recruitment of specific motor units to produce a smooth muscle action. From the standpoint of neural control the fast-twitch and slow-twitch motor units are selectively recruited and modulated in their firing pattern to produce the desired response.

In accordance with the size principle, the slow-twitch motor units, with the lowest threshold for activation, are selectively recruited during lighter effort. These slow-twitch fibers are activated during sustained activities. For more rapid powerful movements, there is a progressive activation of the more powerful fast-twitch fatigue-resistant (type IIa) fibers up through the fast-twitch fatigable (type IIb) when peak force is required.

The ability to use a greater portion of all fibers could indeed result in a greater vertical jump. The slow twitch fibers would need to be recruited in such and effort in accordance with the size principle and the ramp like recruitment of muscle fibers. Slow twitch fibers are innervated by neurons which have smaller axon diameters. These fibers are recruited at lower force levels and show greater fatigue resistance. Fast twitch IIa fibers are generally innervated by neurons with medium diameter axons and produce medium force. Fast twitch IIb fibers are innervated by the larger neurons with the larger diameter axons and produce the greatest force.

Wilmore and Costill (1988) stated that the ramp like recruitment theory asserts that increasing stimulus strength to the muscle will first turn on the slow twitch, and then as stimulus increases the fast twitch IIa, and finally the fast twitch IIb fibers. This theory is in line with the size principle, which states that the smaller size of the slow twitch neuron body makes it easier to recruit motor units with fewer neural signals, whereas the larger fast twitch cell body requires greater stimulation. Perhaps the neural pathways can be enhanced and greater fiber recruitment can be attained with plyometric training.

CHAPTER III

Research Design and Methodology

Subject Selection:

Subjects (N=20) were chosen from an NCAA Division II college in, Parkersburg, West Virginia. Men and women (age 21.5 $\pm$ 3.5 y.r) from the sports of soccer, volleyball, cross country, basketball, baseball, and softball. Subjects varied from freshman to seniors; all were informed of the procedures and were asked about their current health history. Subjects were asked about any lower extremity injury that they may have had in the past year. Subjects then signed a release form to participate in the study. This study was approved by the Marshall University Institutional Review Board (Appendix A).

Instrumentation:

The instruments used in this study were a Biodex System II Dynamometer (Biodex Medical Systems, Shirly, NY). Validity and reliablility statistics for the Biodex System II Dynamometer were reported by Brown et al. (1993). Testing was performed using hard deceleration cushion (0), and a medium lever oscillation sensitivity (c) setting. Only moderate verbal encouragement was given throughout the test which was giving basic kick/pull instructions and number of repetitions remaining. The Biodex™ was calibrated prior to the data collection and after every ten subjects as described by Biodex™ for testing protocols. The vertical jump mat that was used was purchased from SBP Products (Sport Books Publisher, Toronto, Canada).

Methods:

Prior to the test the subject cycled for five minutes on a stationary bike at low intensity to warm up and then complete three repetitions of 20 seconds of bilateral hamstring and calf muscle stretches.

The subjects then completed the vertical jumps using the vertical jump mat. The subject was positioned on the mat with feet on the manufactured foot prints. Then the waist strap was secured around the waist at the level of iliac crest. The waist strap is used to attach the subject to the jump mat via a cord that adjusts for height. This cord was then pulled tight to remove all slack form the subject to the mat, and allowing the measuring tape to be pulled tight and set at 0 (Figure 1, Appendix B). The vertical strap from the waist to the mat was pulled tight and locked. The measuring tape was then unlocked at the mat and the subject was instructed to complete the vertical jump. Subjects used a countermovement based on their own comfort and unrestricted arm swing (Figure 2, Appendix B). A total of three jumps were recorded.

Following vertical jump tests the subjects were then tested on the Biodex™. Subjects were tested both dominant and non-dominant limb in concentric/concentric knee flexion and extension. The standard testing protocol for knee flexion and extension using the Biodex™ was used. Speeds and repetitions for this test were five repetitions at 60, 10 repetitions at 180, and 15 repetitions at 300˚/sec. There was a 45 second rest time between sets and a four minute rest between testing sides. The Biodex™ dynamometer was calibrated every ten subjects as described by Biodex™ for appropriate testing procedure. The subject was placed in the seat and positioned as described by Biodex™ for knee testing. The subjects' knee was then aligned with the axis of the lever arm attached to the power head. The pad of the lower leg attachment was positioned 3 finger widths above the lateral malleolus. The waist strap was pulled tight and the quadriceps strap was pulled secure to allow three fingers between the leg and the strap. Subjects were asked to cross their arms in front of the chest during the test (Figure 3, Appendix

B). Dominance was determined by asking the subject if he or she were to kick a ball which leg would they use, which was a technique described by Ghena et al. (1991)to determine dominance.

The non-dominant limb was tested first and when that part of the test was completed the subject had 4 minutes rest while the dynamometer was set up to test the dominant limb (Figure 4, Appendix B).

Data Analysis Procedures:

The data collected for each subject was collected and separated into dominant leg, peak torque, and time to peak torque. The scope of the study was to evaluate peak torque versus vertical jump and time to peak torque to vertical jump. Data was compiled and a correlation was done using a Pearson R statistical analysis. Statistical Package for the Social Sciences 11.01® (Chicago, Ill. 2001) was the program that was used to run the correlation with a significance level set at $p < 0.05$.

CHAPTER IV

Presentation of the Results of Analysis of Data

Following the testing procedures the data were compiled and mean values were found for the subjects and also the results for each test. The data was also broken down into trial of peak torque, time to peak torque, and vertical jump for all subjects in the test.

Descriptive Data:

The subjects that participated in this study were college age athletes including males and females (age 21.5 $\pm$ 3.5 y.r). The study consisted of a total of 20 subjects (N=20) eleven males and nine females. Of the subjects, 17 reported their right leg as being dominant and three were left side dominant. Mean height was 68.65″ and mean weight was 166.45 lbs. (Table 3, Appendix C)

Vertical jump scores ranged from a low of 13.25″ to a high of 29″ with an mean jump of 18.47″. (Table 3, Appendix C)

Data recorded for peak torque showed an average of 124.205 ftlbs with a range of 201.2 to 67.6 ftlbs at 60°/sec. Peak Torque at 180°/sec ranged from a low of 45.8 to a high of 131.5 ftlbs with an average of 88.59 ftlb. Values of peak torque at 300°/sec had an average of 77.575 ftlbs with a high of 136.7 to a low of 39.4 ftlbs.

Time to peak torque averaged 467msec at 60°/sec with a high of 2810 and a low of 10 msec. The average time to peak torque at 180°/sec was 255.5 and the low was 100 msec and the high value was 450 msec. Time to peak torque at 300°/sec averaged 207 msec and the low was 40 msec and the high was 330 msec. Individual subject data can be found in Appendix C Table 2. All collected data is recorded in Table 1, Appendix C.

Analysis of the Data:

The data that were gathered for the study consisted of an isokinetic test and a vertical jump test. The isokinetic test consisted of bilateral comparison of the muscles of the knee joint. However, the scope of this study was to evaluate the dominant limb. Dominance was achieved by asking the subject if he or she were to kick a ball which leg would they use, which was a technique described by Ghena et al. (1991) to determine dominance. Each isokinetic test gave values of peak torque and time to peak torque extension.

Vertical jump data consisted of values taken as the subject completed the three vertical jumps. The recordings were taken directly off of the measuring tape of the vertical jump mat. The individual jumps were recorded in inches to the nearest quarter inch. The data were gathered and collected as peak torque as an entire group. Also vertical jump scores were not altered in any way they were not averaged and all values for vertical jump were put into the correlation. Vertical jump scores were not separated based on gender or level of activity. Individuals were not separated based on gender, or isokinetic test speed. The values for the correlation were peak torque versus vertical jump, and time to peak torque versus vertical jump. The analysis was made using SPSS 11.01®. Pearson R correlation analysis was used due to continuous variables, and that for this study the relationship between variables was in question.

The null hypothesis which stated there is no significant relationship between vertical jump height and time to peak torque is accepted and the null hypothesis of there is no significant relationship between vertical jump and peak torque is rejected.

General Findings:

In this study there was a significant correlation between vertical jump and peak torque at the speed of 300˚/sec. The value of 300˚/sec peak torque when correlated to vertical jump there was found to be a level of significance at $p=0.019$. There was no significant correlation between time to peak torque and vertical jump across the tested speeds (Appendix C table 4). In general it was found that strength alone at the highest tested speed of 300˚/sec was a better predictor of vertical jump then time to peak torque.

CHAPTER V

Summary, Conclusions, and Recommendations

The study showed that the vertical jump had a significant correlation to peak torque at the highest tested speed. This shows that the speed of the isokinetic test related to the speed and power of the vertical jump test.

Summary and Conclusions:

The goal of this study was to determine if there was a correlation between time to peak torque and vertical jump or a correlation between peak torque and vertical jump. It was found that there was a significant correlation between peak torque at 300˚/sec and vertical jump. The testing speeds during the isokinetic component of the test were broken up to determine if speed did have a relationship and resulting data shows that the pure power found during knee extension is related to maximum vertical jump height at higher speeds.

Interpretations of the Findings:

The subjects that participated in this study were college age athletes males and females (age 21.5 ± 3.5 y.r). The study consisted of a total of 20 subjects including eleven males and nine females. It was found that peak torque when correlated to vertical jump showed a significant relationship at the $p < 0.05$ level of significance. In the study it was found that the relationship between vertical jump and peak torque at a speed of 300˚/sec resulted in a $p = .019$ and an r value of .521 (Table 4, Appendix C).

The results of this study show that the vertical jump is a fast ballistic test used to evaluate muscle power. When correlating that to power of the quadriceps there was a significant relationship found. The vertical jump is a test that uses many more muscle groups then those tested here however, in this study quadriceps peak torque at 300˚/sec is significantly related to vertical jump height.

Discussion of the Findings:

The goal of this study was to find if there are any predictors of vertical jump height in athletes. It was found that there is a correlation to vertical jump and peak torque of the quadriceps. After the results of this study the null hypothesis which stated there is no significant relationship between vertical jump height and time to peak torque is accepted and the null hypothesis of there is no significant relationship between vertical jump and peak torque is rejected because of the significant finding in this study, showing that the vertical jump is a power test of the lower extremity especially the quadriceps muscle group.

Maximum power development during the double leg press power test as reported by Thomas et al. (1996) was related to vertical jump height and maximum strength suggesting that strength is a key component of power development and that the vertical jump is a suitable field test for evaluating explosive leg power. This data also suggests that training interventions that incorporate activities in this range of power development need to be evaluated with regard to their effects on enhancing or increasing muscle power production.

Wilklander and Lysholm (1987) found a significant correlation between isokinetic knee peak torque at the angular velocity of 180˚/sec and vertical jump height.

Recommendations for Future Research:

Following this study the recommendations for future research include;

1. For this particular study the vertical jump is comprised of many different segmental movements as described by Kreighbaum et al. (1996) and that evaluating knee extension is one part of the whole picture. In future research there should be an evaluation of ankle plantartflexion, hip extension, and shoulder flexion. The other joints that comprise the vertical jump may show the same finding that peak torque correlates significantly to vertical jump or can show that the time element of time to peak torque will influence vertical jump height.

2. Other recommendations that can be made are to look at different age groups. In the college age athlete there is more physical maturation and stronger athletes then perhaps at the high school age.

3. The non-dominant limb can be evaluated to find any strength gaps between legs that can improve jump height.

4. A larger sample size is also needed. The current study evaluated 20 subjects and a larger sample would be needed to have more statistical power.

5. Testing between sports could also be done. Vertical jumps of basketball players may be drastically different then cross county runners.

6. Also a comparison between male and female subjects should be evaluated, and multiple tests can be done with athletes' in-season and pre and post seasons.

7. The current study also tested individuals that had not been on an isokinetic machine and the level of apprehension could have been high even through the practice repetitions they received.

Recommendations of a Practical Nature:

The study determined the relationship of peak torque of the quadriceps muscle group to vertical jump height. In using this information the data suggests that training athletes for a vertical jump should include quadriceps strength training. By implementing exercises that will develop and enhance quadriceps strength the vertical jump will be affected also in a direct relationship. In the study done by Nagano et al. (2001) they discussed the ways to improve vertical jump and leg strength. The muscles involved need to be worked out so they become stronger and also the athlete needs to feel comfortable in their jumping so they must also practice the vertical jump as well.

Pate (2000) reported that there should be no assumption that plyometric training affects only type IIa and Type IIb muscle fibers. Even type I fibers can reach peak tension in 1/10th of a second which is time enough for jumping. The true benefit of plyometric training might be to intensify the effort to such a degree that type IIa and IIb fibers might be recruited.

Exercises that enhance the stretch shortening cycle should be use when training muscles for that type of sport or activity. Plyometric training is a technique that uses the stretch shortening cycle and jumping components of athletics. Plyometrics can be done during the entire sports season. There is a low, medium and high level of plyometric exercise that can be used in a training program. Also resistance training needs to be incorporated into the training program. Especially for jumping the areas of emphasis should be on the ankle plantarflexors, knee extensors, and hip extensors.

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Appendix A

Informed Consent Form

Informed Consent Agreement

Title: Correlation between time to peak torque and peak torque in relation to vertical jump height.

Purpose: To use information given by isokinetic testing and relate it to vertical jumping to determine athletic performance and muscle power.

What you will do in the study: I will provide a brief medical history. Height and weight will be taken, a brief warm-up on a stationary bike, and stretching. Then I will perform 3 vertical jump tests, and then an isokinetic test on the Biodex Dynamometer.

Risks: I understand that I may strain a muscle in my lower leg.

Confidentiality: All information obtained in this study will remain confidential as the law and institutional policy allows. The information may be reviewed by appropriate Federal and State agencies as well as the Marshall University Institutional Review Board.

Voluntary Participation: My participation in this study is completely voluntary. There will be no penalty placed on me for not participating in the study.

Right to Withdraw: I have the right to withdraw from this study at anytime without penalty. If I withdraw I will tell the examiner and leave the testing area.

Payment: I will receive no payment for my participation in this study. In the event of injury or illness as direct result of participation in this research study, no compensation, financial or otherwise will be available from the investigators or Marshall University.

Contact: If I have any questions about this study, I may call Craig Kowalski at (304)865-6288 or Dr. Dan Martin at (304)696-2412. If I have any questions regarding my rights as a research subject, I may contact the Marshall University Institution Review Board at 1542 Spring Valley Drive, Huntington, WV. 25755 or by phone at (304) 696-7320.

Agreement: I have read the consent form and understand the nature of this study. I agree to participate in this research study described above.

Participant's Signature: ____ Date:___________

Investigator's Signature: ____ Date:___________

Witness: ____ Date: ___________

Appendix B

Instrumentation and Positioning

Figure 1: Subject in starting position on the vertical jump mat.

Figure 2: Subject ready to perform vertical jump test

Figure 3: Subject starting position for isokinetic test.

Figure 4: Subject performing knee extension during isokinetic test.

Appendix C

Statistical Tables and Results

All data collected for each subject tested. Isokinetic values, vertical jump scores, sex, and dominant leg.

Table 1

leg/sex	Peak Torque Ext	Time to PT Ext	VJ (in)	Deg/sec
R/M	173.3	450	24.5	60
	131.5	320	24.25	180
	136.7	250	29	300
			25.91666667	
R/M	116.9	440	22.25	
	102.3	360	24	
	89.1	250	23	
			23.08333333	
L/M	184.6	310	24.25	
	115.5	170	24.5	
	92.9	140	24.75	
			24.5	
R/M	201.2	320	15.5	
	113.1	190	15.5	
	124.2	170	14	
			15	
R/F	125.1	330	16	
	91	270	17	
	86.4	270	17	
			16.66666667	
L/F	67.6	530	16.5	
	45.8	420	16.25	
	46.5	310	17	
			16.58333333	
R/M	116	170	21.5	
	79.9	100	22.5	
	74.3	100	24	
			22.66666667	
R/M	160	380	21	
	90	210	22	
	91.9	240	22.5	
			21.83333333	

L/F	78.9	500	16.25	
	45.8	450	16	
	48.4	330	16	
			16.08333333	
R/F	102.5	440	22.75	
	77.3	240	23.5	
	82	40	22.5	
			22.91666667	
R/F	77.1	360	13.5	
	48.6	180	13.25	
	45.7	260	15.25	
			14	
R/M	152.1	300	19.5	
	105.9	180	19.5	
	90.3	260	17	
			18.66666667	
R/M	174.5	10	15	
	117.2	110	15	
	88.9	130	14.5	
			14.83333333	
R/F	71.2	410	14	
	66.7	390	13.75	
	39.4	230	14	
			13.91666667	
R/F	113.4	180	15	
	80.4	200	15.75	
	57.4	170	15.25	
			15.33333333	
R/F	103	2810	17	
	93.5	280	17.5	
	74.2	210	16.75	
			17.08333333	
R/M	127.7	360	16	
	110.1	300	15.75	
	82.8	230	16.14	
			15.96333333	

R/M	117.9	350	17	
	98.3	290	16.5	
	74.8	150	16.75	
			16.75	
R/F	113.4	180	15	
	80.4	200	15.75	
	57.4	170	16	
			15.58333333	
R/M	107.7	510	22	
	78.5	250	21.75	
	68.2	230	22.25	
			22	
Average	97.59827586	309.8333333	18.469	

All data gathered per trial at all tested speeds and vertical jump average for each subject tested.

Table 2

Peak Torque			Time To Peak Torque			Vertical Jump
60˚/sec	180˚/sec	300˚/sec	60˚/sec	180˚/sec	300˚/sec	
VAR00001	VAR00002	VAR00003	VAR00004	VAR00005	VAR00006	VAR00007
173.30	131.50	136.70	450.00	320.00	250.00	25.92
116.90	102.30	89.10	440.00	360.00	250.00	23.08
184.60	115.50	92.90	310.00	170.00	140.00	24.50
201.20	113.10	124.20	320.00	190.00	170.00	15.00
125.10	91.00	86.40	330.00	270.00	270.00	16.66
67.60	45.80	46.50	530.00	420.00	310.00	16.58
116.00	79.90	74.30	170.00	100.00	100.00	22.66
160.00	90.00	91.90	380.00	210.00	240.00	21.83
78.90	45.80	48.40	500.00	450.00	330.00	16.08
102.50	77.30	82.00	440.00	240.00	40.00	22.92
77.10	48.60	45.70	360.00	180.00	260.00	14.00
152.10	105.90	90.30	300.00	180.00	260.00	18.66
174.50	117.20	88.90	10.00	110.00	130.00	14.83
71.20	66.70	39.40	410.00	390.00	230.00	13.92
113.40	80.40	57.40	180.00	200.00	170.00	15.33
103.00	93.50	74.20	2810.00	280.00	210.00	17.08
127.70	110.10	82.80	360.00	300.00	230.00	15.96
117.90	98.30	74.80	350.00	290.00	150.00	16.75
113.40	80.40	57.40	180.00	200.00	170.00	15.58
107.70	78.50	68.20	510.00	250.00	230.00	22.00

Table 3

Subject	Height (in)	Weight (lbs)
1	67	122
2	64	120
3	73	170
4	70	276
5	64	120
6	67	160
7	68	162
8	66	158
9	70	165
10	68	166
11	71	162
12	69	145
13	63	123
14	67	160
15	73	253
16	70	179
17	71	199
18	74	180
19	68	134
20	70	175
	68.65	166.45

Height and weight measurements for each subject tested and a mean value of height and weight.

Table 4

Correlations

		PT 60˚/sec	PT 180˚/sec	PT 300˚/sec	TTPT 60˚/sec	TTPT 180˚/sec	TTPT 300˚/sec	VJ
Var 1	Pearson Correlation	1	.865**	.871**	-0.216	-0.536**	-0.303	0.333
	Sig. (2-Tailed)	.	0	000	0.36	0.015	0.194	0.151
	N	20	20	20	20	20	20	20
Var 2	Pearson Correlation		1	.865**	-0.033	-0.37	-0.315	0.377
	Sig. (2-Tailed)		.	000	0.899	0.108	0.176	0.102
	N		20	20	20	20	20	20
Var 3	Pearson Correlation			1	-0.051	-0.286	-0.207	.521*
	Sig. (2-Tailed)			.	0.83	0.221	0.382	0.019
	N			20	20	20	20	20
Var 4	Pearson Correlation				1	0.234	0.132	-0.02
	Sig. (2-Tailed)				.	0.321	0.58	0.933
	N				20	20	20	20
Var 5	Pearson Correlation					1	.634**	-0.092
	Sig. (2-Tailed)					.	0.003	0.701
	N					20	20	20
Var 6	Pearson Correlation						1	-0.218
	Sig. (2-Tailed)						.	0.356
	N						20	20
Var 7	Pearson Correlation							1
	Sig. (2-Tailed)							.
	N							20

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

There is a significant correlation between peak torque at 300˚/sec (variable 3) and vertical jump (variable 7).

PT: Peak Torque
TTPT: Time to Peak Torque
VJ: Vertical Jump