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A comparison of isokinetic eccentric strength training and the transfer to high-velocity concentric strength

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by

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DEDICATION

This thesis is dedicated to my parents, Jerrel and Dorothy Cagle, and to close friends and neighbors, Ed and Irene Walsworth. I learned the value of an education from these loving individuals and this thesis is a direct product of those formative years.

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CHAPTER 1. INTRODUCTION

Hislop and Perrine first introduced the concept of isokinetic exercise in the 1960's. Since the introduction of this concept of accommodating resistance, several isokinetic devices were developed and numerous studies regarding isokinetic strength and strengthening parameters have been published.

Many researchers utilize isokinetic strength training techniques involving concentric muscle contractions. They have reported conflicting data, however, regarding the transfer of isokinetic strength. Moffroid, Wipple, Hofkosh, Lowman, and Thistle (1969) reported the interesting phenomenon of an increase in strength at velocities equal to or less than the training velocity. Other authors (Coyle, Feiring, Rotkis, Cote, Roby, Lee, and Wilmore, 1981; Timm, 1987) report that the training velocity was nonspecific and affected velocities less than and/or greater than the training velocity. The knowledge of these strengthening effects has become an important factor in the determination of the rehabilitation and strengthening program for musculoskeletal injuries.

With the advent of the isokinetic concept, dynamometers capable of determining isokinetic strength were developed. The Cybex (Lumex Inc., Ronkonkoma, NY) was one of the first devices. The early isokinetic dynamometers were capable of determining both isokinetic and isometric strength of concentric muscle contractions at velocities from 0 to 300 degrees per second (^{o}/sec).

Athletic movements vary greatly in specificity of the angular velocity for the sport. Walking requires a movement velocity of 220 to 300^{o}/sec for the knee. The action of punting a football or soccer ball requires a movement at a velocity much greater than 300^{o}/sec. During athletic participation, many movements require eccentric muscle contractions for deceleration, change of direction, and jumping. The early dynamometers were not capable of testing either the high velocities of concentric muscle contractions or determining the strength of eccentric muscle contractions.

Recently, isokinetic dynamometers were developed which test high velocity strength (300 to 500^{o}/sec) and the isokinetic force of an eccentric muscle contraction. The Biodex dynamometer (Biodex Corp., Shirley, NY), the Lido dynamometer (Loredan Biomedical Inc., Davis, CA), and the Kin-Com dynamometer (Chattecx Corp., Chattanooga, TN) are devices capable of testing the strength of both concentric and eccentric muscle contractions at velocities up to 500^{o}/sec. The Kin-Com has been used frequently in studies of the eccentric strength and the transfer of eccentric strength training to concentric strength.

Recent studies failed to demonstrate the effect of the eccentric training on concentric muscle contractions at high velocities (Duncan, Chandler, Cavanaugh, Johnson, and Buehler, 1989), or the functional aspect of eccentric training for the tennis serve (Ellenbecker, Davies, and Rowinski, 1988). However, the concept of eccentric training remains an important construct for the rehabilitation of injured athletes.

It is important to note that the benefits of isokinetic training involving concentric muscle contractions are positive in terms of strength gains and lack of residual muscle soreness. This is one of the few types of strength training in which muscle soreness does not develop. However, one of the drawbacks of isokinetic strength training utilizing eccentric muscle contractions is delayed onset muscle soreness (Davies, 1985). The development of this muscle soreness is recognized as a possible contributory factor in the results of eccentric strength studies. Therefore recent studies have modified training techniques and/or prophylactically treated the onset of muscle soreness in an attempt to prevent the occurrence (Duncan et al., 1989; Ellenbecker, Davies, and Rowinski, 1988; Komi and Buskirk, 1972).

Problem Statement

The purpose of this study was to determine if isokinetic eccentric strength training of college students at 120^{o}/sec has a significant muscle strength transfer to isokinetic concentric movements at velocities up to 450^{o}/sec.

Hypothesis

It was hypothesized that eccentric strength training will have a significant effect on eccentric strength post-test results of both the trained and contralateral legs at the velocities of 60 and 120^{o}/sec; and that eccentric strength training will have a significant transfer effect on both the trained and contralateral leg's post-test concentric strength at velocities between 60 and 450^{o}/sec.

Definition of Terms

The following terms used in this study are defined below:

Accommodating resistance. The resistance of an exercise device which automatically matches the user's immediate and specific muscular capacity at all points during the full range of motion is defined as accommodating resistance (Hislop and Perrine, 1967).

Angular velocity. Angular velocity is known as the angular displacement divided by time (Hay and Reid, 1987).

Biodex. The Biodex is an advanced tool for rehabilitative medicine, exercise, and performance evaluation. It is a device against which a subject can exert his maximal force and muscular imbalances can be determined. The Biodex offers the comprehensive capability of functioning in isometric, isokinetic, passive, or eccentric modes of operation. It can be preset to a constant angular velocity between zero and 450^{o}/sec in the isokinetic mode or between zero and 120^{o}/sec in the passive or eccentric mode (Biodex Operations Manual, 1985).

Concentric contraction. A concentric contraction involves a shortening muscle contraction where the muscle's origin and insertion attempt to approach each other (Davies, 1985).

Debilitating leg injury. A debilitating leg injury is any previous trauma to the quadriceps, hamstring, or internal structures of the knee that rendered an athlete dysfunctional from his sport for more than five days (Ghena, 1988).

Delayed onset muscle soreness. The onset of muscle soreness 24 to 48 hours following the cessation of the exercise bout (Talag, 1973).

Dominant leg. The dominant leg is the neuromuscularly superior limb as defined by the subjects's preference in kicking a ball (Rankin, 1983).

Eccentric contraction. An eccentric contraction involves a lengthening muscle contraction where the muscle's origin and insertion separate (Davies, 1985).

Extension. Extension is a movement which increases the angle at the joint.

Flexion. Flexion is the movement which decreases the angle at a joint.

Full range of motion. The angular displacement through which a limb can move, limited only by structural characteristics of the joints, is defined as full range of motion (Wheeler, 1984).

Isometric contraction. An isometric contraction occurs when a resistance acting on a skeletal lever is sufficient to prevent motion (Hislop and Perrine, 1967).

Isokinetic contraction. An isokinetic contraction occurs when a resistance is moved through a full range of motion at a constant velocity with maximal tension on the muscle at all joint angles (Hislop and Perrine, 1967).

Power. The ability to produce force through a range of motion in a particular time (Davies, 1985).

Limitations

A study of this scope and nature requires that several limitations be recognized:

1. The subjects in the study may have lacked sufficient motivation during the training and testing portions of the study thus affecting their performance;

2. The time frame for the eccentric strength training program (three weeks) may not be sufficient to produce physiological changes in muscle strength, rather it will affect only the neural component of force production; and,

3. Delayed onset muscle soreness may contribute to both subject withdrawal rate and post-test results.

CHAPTER 2. REVIEW OF RELATED LITERATURE

Eccentric muscle contractions and the relative strength generated during isokinetic strength testing of these contractions are different than concentric muscle contractions and the linear regression of the concentric strength-velocity relationship. The differences exist not only in the myofibrillar crossbridging action and the lengthening of the z-bands (Friden, 1984) but also in the reduced myofibril recruitment during contraction (Tesch, Dudley, Duvoisin, Hather, and Harris, 1990; Bigland-Ritchie, and Woods, 1976), and the significantly greater strength generated by eccentric contractions (Davies, 1985). The purpose of this study was to determine if isokinetic eccentric strength training at 120^{o}/sec has a significant muscle strength transfer to isokinetic concentric movements at velocities up to 450^{o}/sec. This review of related literature will examine isokinetic concentric strength; eccentric strength; a comparison of concentric and eccentric strength parameters; and, testing equipment.

Isokinetic Concentric Strength

Hislop and Perrine (1967) introduced the concept of strength training using an accommodating resistance. According to Davies (1985) isokinetic exercise is essentially the opposite of isotonic exercise due to the differences in resistance (fixed or accommodating) and muscle loading.

Specificity of exercise and strength training are important factors of training or the rehabilitation of an injury. The specificity of the isokinetic, isometric, and isotonic strength training modes is well established (MacDougall, Ward, Sale, and Sutton, 1977; MacDougall, Sale, Moroz, Elder, Sutton, and Howold, 1979; Davies, 1985; Kanehisa and Miyashita, 1983), however conflicting reports exist (Davies, 1985; Moffroid et al., 1969; Smith, 1981; Coyle et al., 1981) regarding the transfer and/or overflow of strength as a result of isokinetic training.

The relevance of the mode specificity is important in rehabilitation. The therapist may apply this knowledge to use the mode or modes of strength training, which is of greatest benefit for the patient. Kanehisa and Miyashita (1983) investigated changes in dynamic and static strength as a result of isometric and isokinetic strength training. The study involved both isometric, and fast ($157^{o} \cdot s^{-1}$) and slow ($73^{o} \cdot s^{-1}$) velocity isokinetic training. The authors report significant improvements from the isometric training in the post-test static and dynamic power calculated as watts, at equivalent masses of 18.3, 31.6, 67.6 kg. for the fast velocity, and 713.7 kg. for the slow velocity, during the six week training period. The second portion of the study involving the fast (157^{o}/sec.) and slow (53^{o}/sec.) velocity training observed a speed specific phenomenon in dynamic power of equivalent masses. The fast velocity training resulted in an increase in post-test strength with equivalent masses of 18.3, 31.6, and 67.6 Kg. Also, the slow velocity training resulted in an increase at the mass equivalent of 713.7 Kg. only. Thus, the findings of this study indicate that both the isometrics and isokinetics are training specific.

MacDougall et al. (1977) observed increases in the triceps brachii strength and muscle girth following isotonic weight training sessions. However, improvements in isokinetic strength were insignificant. The 1979 study by MacDougall et al. was a repetition of the 1977 isotonic study with the incorporation of a three day per week training session using an isokinetic dynamometer. The combined isotonic and isokinetic training replicated the previous results and demonstrated a significant increase in isokinetic strength. The results of these studies indicate the specificity of isokinetic and isotonic strength.

The phenomenon of overflow from the training velocity to slower or faster training velocities during isokinetic training frequently reported. Coyle et al. (1981) reported significant increases in peak torque at velocities of 0, 60, 180, and 300^{o}/sec using placebo, slow, mixed, and fast velocity training groups. The slow training group (60^{o}/sec) demonstrated a significant improvement in percent change of 20, 32, and 9% for the peak torques at the velocities of 0, 60 and 180^{o}/sec. The fast training group (300^{o}/sec) developed a percent change of 15 to 24% for the four test velocities. The mixed training group (60 and 300^{o}/sec) improved the peak torques with percent increases of 23.6% for 60^{o}/sec and 16.1% for 300^{o}/sec. The mixed training group also developed a significant increase at 180^{o}/sec, even though the percent change (8%) was markedly less than the training velocities. The results appear to indicate the existence of the overflow phenomena from the fast to the slow velocity and from the slow to the intermediate velocity. Also, the study demonstrates that mixed velocity training does not produce the percent change results of speed specific training.

The cascade or overflow effect of velocity training is a controversial factor. Reports indicate that strength increases occur at the training velocity and at velocities slower than the training velocity (Lesmes, Costill, Coyle, and Fink, 1978). This is an important factor, because training periods could be reduced thus decreasing the impact of fatigue while simultaneously improving strength at the slower velocities. The 1978 study by Lesmes et al. investigated the power and strength gains as a result of isokinetic training at a velocity of 180^{o}/sec, for a training duration of six and 30 seconds per session. Increases in peak torque at velocities of 0, 60, 120, and 180^{o}/sec were found. However no significant changes were noted at the velocities of 240 and 300^{o}/sec. It was concluded that "isokinetic training can increase muscular power and possibly alter the fatigability of the muscle" (Lesmes et al., 1978).

Power is the amount of force produced through the range of motion in a particular time (Davies, 1985). The concept of isokinetics allows for the measurement and training at velocities which are considered to be power (greater than 60^{o}/sec) contractions (Davies, 1985). Conflicting reports exist regarding the effect of high velocity power training and low velocity strength training. Garnica (1986) reports that the slow velocity training resulted in 18 and 10% increases for the slow training velocity and the fast training velocity. However, the group using the fast training velocity exhibited a speed specific increase of 18% at the fast velocity of 180^{o}/sec, but only a 4% increase at the slow velocity. The results of this four week, three session per week training protocol indicate that the slow velocity isokinetic training has a transfer effect to fast velocity power, and the fast velocity training appears to be speed specific.

Stratton (1984) investigated the improvements in isokinetic strength and power of the quadriceps during a five week, two session per week training program. The 24 previously trained and untrained subjects performed a two pyramid scheme of training at 60^{o}/sec and a power endurance training bout of 30 seconds at 240^{o}/sec during each session. Significant increases of peak torque were reported during the final post-test for the trained group at 60 and 240^{o}/sec and for the untrained group at 60^{o}/sec. The results of this study demonstrate to some degree the specificity of isokinetic training, but fail to explain the lack of power gains for the previously untrained subjects.

Up to this point, the application of isokinetic concentric strength training to sport has not been discussed. The relevance of isokinetic training and the direct relationship to improvements in athletic performance are important concepts for athletes, coaches, and athletic trainers. Swimming is one of the few sports for which an isokinetic device is available that mimics the mechanics of the sport. The relationship between muscular power and sprint freestyle swimming was studied by Sharp, Troup, and Costill (1982). Forty male and female swimmers were tested, during their competitive season, for bilateral arm power with a Biokinetic Swim Bench at velocities ranging from 1.60 to 3.28 $m \cdot s^{-1}$. Peak power and performance were measured during the five test-retest bouts. The swimmers were also tested for fatigability during repeated 25 yard freestyle sprints. A correlation (r=.90) was reported between swim power and sprint freestyle performance. The fatigability of the swimmers was found not to be a factor (r=.01) in sprint performance. The swimmers also demonstrated increases in power (watts) and sprint swim velocity in comparison to the final post-test and the pre-test. The study illustrated the practical application of power tests and performances if the power measurement apparatus is specifically applicable to the event.

In conclusion, research indicates that concentric isokinetic strength training increases both muscular strength and power. However, the specificity and/or transfer of the strength from one velocity to another remains unclear.

Eccentric Strength Training

An eccentric muscle contraction is one in which the muscle lengthens during force production. Astrand and Rodahl (1986) describe this as, "a contraction of a muscle which is too weak to overcome the resistance imposed, so that the length of the muscle increases." Eccentric contractions can be generated during daily activities by walking or running down stairs or hills, and in virtually any physical activity which requires jumping or rapid deceleration of the movement.

Until the advent of the Biodex, Kin-Com, and Lido dynamometers, eccentric strength training consisted of adding weight to the bar following a concentric contraction during weight lifting, step-tests, running downhill, or riding specially modified cycle ergometers. With the previously mentioned isokinetic apparatus, a subject is capable of eccentric strength training without the cumbersome modification of equipment and/or dangerous training regimens.

Studies involving eccentric strength training have examined concepts, damage to muscle and ultra structure, and the resulting soreness due to the eccentric contractions. The action of an eccentric contraction is the reverse of concentric contraction. The mechanism requires the breaking of phosphorus bonds at the myosin and actin cross bridging sites, thus allowing the lengthening process to occur. Stauber (1989), in a review of the eccentric action of muscles, reports that eccentric contractions can cause both direct and delayed myofibril damage and damage to connective tissue. Stauber indicates that the damage to these structures could be contributory to both spontaneous and delayed onset of pain.

Structural damage of the myofibril units as result of eccentric exercise is indicative of the force necessary to overcome the concentric contraction. Reports of specific damage include alterations to both the z-bands and z-disc following eccentric training (Friden, 1984; Friden, Sjostrom, and Ekblom, 1983). Alterations to z-bands and z-disc structures predominantly occur in Type-2 muscle fibers (Friden, 1984; Friden, Sjostrom, and Ekblom, 1983). However, the damage to these structures was reported to be repaired within a week (Friden, 1983). Friden (1984) concluded that the myofibril adaptations to eccentric training "probably results in better stretchability of the muscle fibers, reduces the risk for mechanical damage and brings about an optimal overlap between actin and myosin filaments."

Reports of eccentric strength training affecting both concentric and isometric strength gains exist in the literature (Singh and Karpovich, 1967). The transfer of eccentric strength training to other modes of strength conflicts with the specificity theories of training, previously mentioned. Singh and Karpovich (1967), using an electric dynamometer, studied the effect of eccentric training of agonists on antagonists muscle groups involved with elbow extension and flexion. The elbow extensor muscles of 10 subjects were trained eccentrically with 20 contractions per session, four sessions per week for a period of eight weeks. Improvements were reported in the agonists post-test results for eccentric (22.9%), concentric (42.8%), and isometric (40.3%) strength of the agonists muscle group. The antagonists muscles also demonstrated improvements in eccentric (16.7%), concentric (30.9%), and isometric (26.4%) strength. The transfer of the agonists strength training to the antagonistic improvements was attributed to the interaction of the agonists during the training process, which was verified by palpation and electromyograms (EMG).

Comparison of Concentric and Eccentric Strength Parameters

The comparative difference of concentric and eccentric strength is frequently reported in the literature as is the results of eccentric training. Reports of the differences in eccentric and concentric contractions not only include strength gains, but also EMG characteristics and the specificity of the eccentric training.

The force production of the eccentric contraction is considerably greater than a concentric contraction (Davies, 1985; Duncan et al., 1989, Ellenbecker, Davies, and Rowinski, 1988; Rizzardo, Wessel, and Bay, 1987). Along with the increase in force, a decrease in the EMG activity level of the muscle fiber occurs with an eccentric contraction (Bigland-Ritchie and Woods, 1976; Tesch et al., 1990). During isokinetic exercise the peak torque output of concentric contractions decreases as the velocity of the movement increases. Hageman, Gillaspie, and Hill (1988) report that eccentric force remains relatively constant with an increase in velocity from 30 to 180^{o}/sec. This finding is similar to the observations of Rizzardo, Wessel, and Bay (1987) in that eccentric output increased from 60 to 120^{o}/sec but declined at 180^{o}/sec.

The characteristics of eccentric and concentric loading of the quadriceps and hamstring muscle groups of college male athletes are reported by Ghena (1988). A Biodex dynamometer was used for measuring both the concentric and eccentric strength. Peak torques of the concentric velocities of 60, 120, 300, and 450^{o}/sec and eccentric velocities of 60 and 120^{o}/sec were analyzed for the quadriceps and hamstrings. The quadriceps demonstrated a greater torque eccentrically than concentrically at 120^{o}/sec. However, at 60^{o}/sec a significant difference did not exist between the concentric and eccentric scores for the quadriceps. The eccentric peak torques of the hamstrings was reported to be greater, at both 60 and 120^{o}/sec, than the concentric results. Also, the results of the eccentric hamstring/quadriceps ratio were reported to be higher than the corresponding concentric results at 60 and 120^{o}/sec.

Differences in the quadriceps eccentric peak torque of females is indicated to be greater than the concentric peak torques. Rizzardo, Wessel, and Bay (1988) report that a difference of 48.19, 85.19, and 76.58 Nm for the eccentric torque was observed at the velocities of 60, 120, and 180^{o}/sec. The average eccentric power of the quadriceps was greater than concentric power (51.7% and 27.8% at 120 and 180^{o}/sec). The Kin-Com dynamometer was used for data collection. The eccentric torques increased from 60 to 120^{o}/sec but the 60^{o}/sec concentric torque was greater than the torques generated at the velocities of 120 and 180^{o}/sec.

Quadriceps and hamstring eccentric and concentric peak torque characteristics of males and females was reported by Highgenboten, Jackson and Meske (1988). The male and female groups were sub-grouped by age. The peak torque values were divided by the subjects' body weight for analysis. A Kin-Com dynamometer was used in the collection of the concentric and eccentric data. A velocity of 50^{o}/sec was used for testing. A significant difference was obtained between the age groups for the concentric adjusted scores. A gender difference was noted in the adjusted peak torques for the male subjects in both the concentric and eccentric test modes.

Strength training appears to be specific to the mode of the training whether it is isokinetics, isotonics, or isometrics. The literature indicates that the isokinetic training is velocity specific with some transfer of strength to both faster and slower velocities. Therefore, a transfer of concentric to eccentric strength either may or may not occur. Reports indicate that concentric training does increase eccentric force (Petersen, Ball, Bagnall, and Quinney, 1989; Petersen, Wessel, Bagnall, Wilkins, Quinney, and Wenger, 1990; Johnson, Adamczyk, Tennoe, and Stromme, 1976), but conflicting reports indicate that eccentric training is mode specific (Duncan et al., 1989) while other reports suggest that great improvements in strength are achieved through mixed concentric and eccentric training programs (Colliander and Tesch, 1990).

A time dependent design incorporating 6 weeks of control followed by 12 weeks of concentric resistance training reports increases in concentric and eccentric strength. The male subjects had previously participated in a strength training program. Peak torques of concentric and eccentric strength were measured on five occasions prior to and during the control period, and following six and 12 weeks of concentric training. The peak torques were measured by a Kin-Com isokinetic dynamometer at a velocity of 1.05 $rad \cdot s^{-1}$. An increase in both concentric and eccentric strength occurs following six and 12 weeks of training according to Petersen, Bell, Bagnall, and Quinney (1989). It was concluded that concentric muscle strength training was not specific to the contraction type when the training is of adequate duration and intensity.

A concentric resistance training study to determine the influence of such training on concentric and eccentric strength was conducted by Petersen et al. (1990). College-age females (n=16) who had not participated in previous strength training regimens were randomly assigned to the control or training groups. The training group exercised at a velocity of 1.05 $rad \cdot s^{-1}$, three days per week at five sets of 10 repetitions per session for a period of six weeks. The isokinetic exercise was performed on a Cybex II+ dynamometer. Pre and post concentric and eccentric strength results were determined by a Kin-Com dynamometer at 1.05 $rad \cdot s^{-1}$. Both the concentric and eccentric strength results were reported to increase in the training group. A decrease was reported in the concentric strength of the control group. The between groups analysis showed an improvement in the training group concentric and eccentric peak torque results. It was concluded from these data that concentric resistance training is not mode specific to the contraction type.

Concentric and eccentric/concentric strength training at a velocity of 1.05 $rad \cdot s^{-1}$ was used to determine the effect on both concentric and eccentric strength. Colliander and Tesch (1990) report that twenty-nine male subjects were randomly assigned to one of the two training groups or the control group. The concentric group trained bilaterally during week one and two at four sets of 12 maximal contractions and during week three through week 12 at five sets of 12 maximal contractions. The eccentric/concentric group performed six pairs of maximal bilateral concentric and eccentric contractions. The eccentric/concentric group demonstrated increases in concentric peak torque at a velocity of 0.52

$rad \cdot s^{-1}$ unilaterally and for the eccentric peak torque contractions of 0.52, 1.57 and 2.62 $rad \cdot sec^{-1}$. Significant differences were expressed for the bilateral concentric test velocity of 0.52, 1.57, 2.62 $rad \cdot s^{-1}$ for the eccentric/concentric training group, but the bilateral eccentric results were not significant for either training group. A significant within training difference unilaterally and bilaterally was reported for both training groups at the three concentric and eccentric velocities. The data suggest that a combined eccentric and concentric training program is of greater benefit than either concentric or eccentric training alone.

A comparison study of isotonic concentric and eccentric strength training was reported by Johnson, Adamczyk, Tennoe, and Stromme (1976). Eight male subjects trained one side concentrically at 80% max and the opposite side eccentrically at 120% max. Two sets of ten repetitions were used for concentric exercise and two sets of six repetitions were utilized for the eccentric training, which occurred three times a week for a period of six weeks. Static and dynamic pre- and post-tests were used to determine the influence of elbow, shoulder and knee flexion, elbow and shoulder extension, and horizontal adduction of the shoulder. Results of the static post-test indicate that a significant change for the concentric trained side in flexion of the shoulder, extension of the elbow and shoulder, and in horizontal shoulder adduction. The eccentric trained side developed significant increases in static strength for flexion of the shoulder and horizontal adduction of the shoulder, and in knee flexion, elbow and shoulder extension. Significant changes occurred in dynamic strength for both the eccentric and concentric trained sides with the arm curl, arm press, knee flexion, and knee extension. Increases in both static and dynamic strength would indicate that isotonic eccentric and concentric training is non specific in the strength training mode.

In a study which investigated the mode specificity of concentric and eccentric strength training, Duncan et al. (1989) reports that eccentric training is mode specific. Also, the eccentric training at 120^{o}/sec invoked changes in eccentric force at 60, 120, and 180^{o}/sec. However, the eccentric training did not demonstrate changes at the concentric velocities. The concentric group demonstrated a percent change (7.8%) at the concentric velocity of 180^{o}/sec only. The interaction between the concentric training, eccentric training and control groups indicated that the percent change in eccentric and concentric force was significantly different between the three groups. It was concluded by Duncan et al. (1989) that eccentric isokinetic strength training at 120^{o}/sec was mode specific and concentric training velocity at 120^{o}/sec produced strength changes at 180^{o}/sec, which was considerably faster than the training velocity.

EMG and torque ratio activity remain constant during eccentric exercise as does torque output over repeated bouts of exercise (Tesch et al., 1990). Tesch et al. (1990) suggest that the lack of change in the eccentric EMG both during and between exercise bouts is a result of "almost no central or peripheral fatigue during repeated eccentric contractions." Similar observations were reported by Bigland-Ritchie and Woods (1976) regarding decreased EMG activity in the muscle vastus lateralis during eccentric cycling. Bigland-Ritchie and Woods (1976) suggest the difference between the eccentric and concentric EMG activity is due to less activity by the muscle fibers during eccentric work.

Information regarding the functional aspect of eccentric strength training is limited because of the mechanism of eccentric training in that the muscle is attempting to prevent or slow down a lengthening process. Therefore, eccentric training could be detrimental to high velocity movements. In a comparison of objective data and a functional test Ellenbecker, Davies, and Rowinski (1988) studied the effects of concentric or eccentric strength training of the rotator cuff. Male and female (n=22) varsity collegiate tennis players were assigned by random stratification to either an eccentric training, concentric training, or control group. Subjects were objectively pre- and post-tested concentrically, with a Cybex II dynamometer, and eccentrically, with a Kin-Com dynamometer, at velocities of 60, 180, and 210^{o}/sec. Functional testing consisted of three maximal tennis serves into the service box in an indoor setting. The serves were documented with high speed cinematography at 100 frames per second. Digital analysis of the fastest serve was used to determine the ball speed. Eccentric and concentric training consisted of a six week period with two sessions per week. Each session consisted of a pyramid velocity spectrum concept (60, 180, 210, 210, 180, and 60^{o}/sec) with six sets of ten repetitions at each velocity. Concentric training with the Cybex II consisted of internal/external rotation with the arm positioned at 90^{o} abduction for the glenohumeral joint. Positioning for the eccentric training placed the glenohumeral joint at 90^{o} adduction. The eccentric training was performed with the Kin-Com dynamometer. The concentric trained group improved considerably at the concentric velocities in both internal and external rotation. Eccentrically, the concentric group improved at 210^{o}/sec in external rotation and at 60 and 180^{o}/sec internal rotation.

The concentric group demonstrated an increase in the ball speed of the tennis serve. The eccentric training group improved in both internal and external rotation in the concentric tests. External rotation at the eccentric velocity of 210^{o}/sec demonstrated improvement by the eccentric training group. The functional test of ball speed indicated that increase did not occur with eccentric group. The functional results of ball serve should be expected due to the deceleration nature of the eccentric contraction. The results indicate that isokinetic concentric training demonstrates a high degree of application to explosive movement such as the tennis serve, and that eccentric training should be avoided. The specificity of training concept is reaffirmed by this study.

Isokinetic Testing Equipment

Isokinetic research is accomplished primarily through the use of the Cybex dynamometer. In recent years technology has evolved and manufacturing capabilities developed to improve upon the initial isokinetic dynamometers. The new dynamometers are capable of velocities of 500^{o}/sec, which is much faster than the original 300^{o}/sec velocity of the Cybex. Eccentric capabilities have been included, in the new isokinetic devices, as either passive movement and/or concentric initiated reactive eccentric modes. The Biodex, Kin-Com, and Lido are examples of the new dynamometers capable of interrupting and initiating both static and isokinetic concentric and eccentric force.

The Biodex System is described by the Biodex Corporation (1987) as the following:

> The Biodex B-2000 is an advanced tool for rehabilitative medicine, exercise, and performance evaluation. BIODEX offers the comprehensive compatibility of providing isometric, isokinetic,

> passive and reactive eccentric modes of operation, each having distinct benefits and uses. The systems Acquisition Control Module (ACM) provides measurement, analysis, and reporting of torque, elapsed time, range of motion, and velocity data associated with all modes of operation (p. 1-1).

The Biodex was developed for clinical use as a rehabilitation and evaluation tool. The use of the device in the research setting has been prohibitive due to the high cost associated with such an isokinetic device.

With any research tool the reliability and validity of the equipment is a concern. Several studies (Feiring et al., 1990; Timm, a & b; Wilk, 1988; Fallstrom, 1987) report the interclass correlation coefficient factor to range from r=.90 to r=.99 for the Biodex. Fallstrom (1987) reports that the validity of the Biodex ranged from a weak correlation of r=.66 to r=.90.

Comparative studies of the Biodex and the Cybex II dynamometers were reported (Thompson et al., 1989; Gross et al., 1990). Thompson et al. (1989) in the evaluation of the Cybex II Plus and the Biodex B-2000 reports that there was enough discrepancies in the data generated by the two dynamometers that care should be used when extrapolating data from one machine to another. However, Gross et al. (1990) suggests that the intermachine reliability between the Biodex and the Cybex II are improved if the range of motion is controlled to remove the Cybex II impact artifact. The current data suggest that differences do exist between the devices. However, changes in the computer software have been proposed for rectification of the problem.

Conclusion

Within this review of related literature the concepts and investigations of isokinetic strength parameters, concentric and eccentric force, and the reliability of the isokinetic apparatus were discussed. The specificity of accommodating resistance training has been demonstrated with uncertainty. Conflicting reports indicate concentric strength evokes changes in eccentric force, yet some reports found this transfer of force to be nonexistent. The testing equipment was shown to be reliable during test and retest trials. The validity of the testing apparatus was shown to have a mild to high correlation score.

CHAPTER 3. METHODOLOGY

The subjects for this study were 18 college students who were enrolled in HLTH 194, Health and Wellness, a physical fitness concept class at Northeast Missouri State University. The Human Subjects Committees from Iowa State University and Northeast Missouri State University granted approval for this study. Subjects read and signed an informed consent document (Appendix A) prior to participation in the study. Subjects who reported a debilitating knee injury during the past year were excluded from the study. The subject data are displayed in Table 1.

TABLE 1. SUBJECT INFORMATION DATA

	AGE (yrs)	STANDARD DEVIATION	HEIGHT (cm)	STANDARD DEVIATION	WEIGHT (kg)	STANDARD DEVIATION
DTG (n=5)	25	±6.18	162.92	±11.97	56.89	±10.19
NTDG (n=7)	21	±1.64	174.87	±8.23	68.53	±12.46
CG (n=6)	21	±1.11	172.12	±10.05	80.41	±24.85
All Subjects	22	±3.85	170.63	±11.11	69.26	±19.41

Subjects were separated into gender groups and randomly assigned to one of the three treatment groups. The treatment groups were designated as dominant training group (DTG), non-dominant training group (NDTG), and control group (CG). To assure equality of numbers and gender between the groups a stratified random sampling was utilized for group assignment.

The three groups participated in two pre-tests and a post-test session. Each test session consisted of six speeds: four concentric speeds of 60, 120, 300, and 450^{o}/sec and two eccentric speeds of 60, and 120^{o}/sec.

Groups DTG and NDTG strength trained their quadriceps isokinetically, at a velocity of 120^{o}/sec, using eccentric muscle contractions. The training sessions consisted of three workouts per week for a duration of three weeks. The participants trained three days per week with a minimum of one day rest between workouts. The individual sessions consisted of two sets of ten repetitions at 70% maximal contraction.

A Biodex B-2000 dynamometer (Biodex Corporation, Shirley, NY) was used for the isokinetic strength training and testing procedures. The Biodex dynamometer was calibrated in accordance with the Biodex Operations\ Applications Manual (Biodex Corp., 1987) prior to each test session. Subjects warmed up at a comfortable rate on a Monarc ergometer at a resistance setting of 1.5 kg. for five minutes before testing or strength training. The subjects were stabilized in the accessory chair by two crossing diagonal chest straps, a lap restraint, a thigh strap, and a strap attaching the lower leg to the powerhead apparatus arm of the dynamometer. For testing purposes, the non-dominant knee was tested first. As a warmup prior to each test speed, the subjects were told to exert two sub-maximal contractions through the full range of motion in accordance with the Biodex recommended testing protocol (Biodex Corp., 1987). The individual test speeds consisted of three repetitions through the full range of motion. The subjects were instructed, prior to each concentric test, to extend and flex their legs with as much force and velocity as they were able to exert. During the warmup phase of the eccentric test, the subjects were instructed to exert sub-maximal resistance in an attempt to prevent the extension and flexion movements of the leg being produced by the Biodex. Immediately prior to the eccentric tests, the subjects were instructed to maximally resist the movement of their leg through three complete motions of extension and flexion.

Dynamometer data readings and data reduction were calculated by the Biodex Bioware (Biodex Corp., 1985) software program on an IBM Personal System 2, Model 30. Reports of the data reduction were compiled by the Bioware and printed on an Epson LX-80 printer.

The Statistical Analysis System (SAS), at the Iowa State University Computation Center using the NAS AS/9160 computer was utilized for data analysis. The percent change difference of the pre- and post-test peak torques at the six velocity test speed variables of the groups was analyzed for means and standard deviations. A 3x2x6 split-plot ANOVA was used to determine the differences between and within groups. Correlation coefficients were determined for the training velocity in comparison to the six isokinetic test speeds. Results of significance are reported at the $p<.05$ level.

CHAPTER 4. RESULTS

The purpose of this study was to determine if eccentric strength training had an effect on high velocity isokinetic concentric strength in trained and untrained legs of the subjects. To compensate for the statistical error which resulted as a product of the individual subject's variability, the difference between pre- and post-test was calculated as percent change. A 3x2x6 split plot ANOVA was utilized to determine the statistical significance of changes within and between the two treatment groups, dominant training group (DTG) and non-dominant training group (NDTG), and the control group (CG). Independent variables also included side (trained and untrained), the four concentric test speeds, and the two eccentric test speeds.

Statistical Analysis

A split-plot 3x2x6 ANOVA design was utilized to determine statistical interaction within and between the three subject groups. The SAS General Linear Models Procedure was used for data analysis. Results of split-plot ANOVA indicate that trends exist in the Speed $F(5,75) = 3.757$, $p<.05$, Side $F(1,15) = 2.116$ $p>.05$ and Side by Speed $F(5,75) = 1.897$, $p>.05$. The split-plot ANOVA results are presented in Table 2.

The limitations of this study regarding the three week, nine session, training period may be reflected in the non-significance of the results. However, the eccentric mode specific, and contralateral transfer trends demonstrated by the data should not be ignored.

TABLE 2. GENERAL LINEAR MODELS PROCEDURE SPLIT-PLOT ANOVA

SOURCE	DF	MS	F
BETWEEN SUBJECTS			
Group	2	314.160	.998
Error	15	314.830	
WITHIN SUBJECTS			
Side	1	506.861	2.116
Group x Side	2	68.776	.287
Error	15	239.516	
Speed	5	426.704	3.757*
Group x Speed	10	132.560	1.167
Error	75	113.569	
Side x Speed	5	155.103	1.897
Group x Side x Speed	10	124.572	1.524
Error	75	81.759	

* Significant at $p<.05$ level

Eccentric Strength Changes

Several trends were present upon examination of the percent change results of eccentric strength training. In both the training and control groups, the percent change results were positive for the training velocity of 120^{o}/sec. The pre-test, post-test, and percent change results for the three groups and the two eccentric velocities are presented in Table 3. The data represents the mean results of the percent change calculations from the pre-test and post-test data, as well as mean scores of the pre- and post-tests. The training groups demonstrated a mean percent change 5.94% (Standard Error = ±2.66) and 9.90% ±3.74 for groups DTG and NDTG repetitively. The CG demonstrated a change of 10.58% ±4.32 at the eccentric velocity of 120°/sec.

There were also improvements in eccentric strength which occurred at the training velocity in the untrained leg. This trend is compatible

TABLE 3. PRE- AND POST-TEST PEAK TORQUE RESULTS OF ECCENTRIC STRENGTH AND MEAN PERCENT CHANGE DIFFERENCES

	VELOCITY	TRAINED				UNTRAINED			
	Degrees Per Second	Mean Pre Peak Torque (ft.lbs.)	Mean Post Peak Torque (ft.lbs.)	Mean Percent Change	SE	Mean Pre Peak Torque (ft.lbs.)	Mean Post Peak Torque (ft.lbs.)	Mean Percent Change	SE
DTG[1] (n=5)									
	60	123.60	136.40	10.38	4.64	119.60	125.40	4.84	2.17
	120	127.20	134.20	5.94	2.66	123.00	123.60	1.80	0.81
NDTG[2] (n=7)									
	60	148.29	166.71	14.40	5.44	158.71	162.86	2.99	1.13
	120	154.51	169.71	9.90	3.74	162.14	165.71	2.64	1.00
CG[3] (n=6)									
	60	144.33	148.50	6.48	2.65	139.50	151.00	9.32	3.81
	120	136.17	146.17	10.58	4.32	145.67	156.33	6.98	2.85

[1] Dominant Training Group
[2] Non Dominant Training Group
[3] Control Group

well as mean scores of the pre- and post-tests. The training groups demonstrated a mean percent change 5.94% (Standard Error = ±2.66) and 9.90% ±3.74 for groups DTG and NDTG repetitively. The CG demonstrated a change of 10.58% ±4.32 at the eccentric velocity of 120°/sec.

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DTG[1] (n=5)									
	60	123.60	136.40	10.38	4.64	119.60	125.40	4.84	2.17
	120	127.20	134.20	5.94	2.66	123.00	123.60	1.80	0.81
NDTG[2] (n=7)									
	60	148.29	166.71	14.40	5.44	158.71	162.86	2.99	1.13
	120	154.51	169.71	9.90	3.74	162.14	165.71	2.64	1.00
CG[3] (n=6)									
	60	144.33	148.50	6.48	2.65	139.50	151.00	9.32	3.81
	120	136.17	146.17	10.58	4.32	145.67	156.33	6.98	2.85

[1] Dominant Training Group
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with the mean percent change results for the trained leg, 1.80% $\pm$0.81 and 2.64% $\pm$1.00, for groups DTG and NDTG repetitively. Group CG demonstrated a markedly greater mean percent change, 6.98% $\pm$2.85, in the non-dominant leg.

The mean percent change trends were also present according to post-test data at the 60°/sec velocity for all groups. The DTG exhibited a markedly high percent change of 10.38% $\pm$4.64 for the trained leg, while 14.40% $\pm$5.44 change was registered by NDTG. The CG demonstrated a 6.48% $\pm$2.65 change in the dominant leg. The untrained contralateral leg data indicated a mean percent change increase for the three groups at the test velocity of 60°/sec. DTG data demonstrated a 4.84% $\pm$2.17 increase and NDTG a 2.99 $\pm$1.13 mean percent change at the slower eccentric velocity. However, the CG data indicates a greater mean percent change 9.32 $\pm$3.81 in the non-dominant than the experimental groups demonstrated in the untrained leg.

The mean percent changes presented by the training groups demonstrated the eccentric training effect within the eccentric mode. The trend regarding the positive increase of the mean percent changes were positive, all of the increases were non-significant results. This non-significant factor may be attributed to the relative short duration of the training period (3 weeks), which may not have allowed enough time or sessions for strength gains to occur.

Concentric Strength Changes

The data indicated that both increases and declines in mean percent change existed at the four concentric test speeds. The high velocity speeds of 300°/sec and 450°/sec demonstrated an increase in mean percent change for both experimental groups and the control group. The concentric isokinetic strength results of the four test velocities are presented in Table 4. The results represent the mean of the percent

TABLE 4. PRE- AND POST-TEST CONCENTRIC STRENGTH RESULTS AND MEAN PERCENT CHANGE DIFFERENCES

	VELOCITY	TRAINED				UNTRAINED			
	Degrees Per Second	Mean Pre Torque (ft.lbs.)	Mean Post Torque (ft.lbs.)	Mean Percent Change	SE	Mean Pre Torque (ft.lbs.)	Mean Post Torque (ft.lbs.)	Mean Percent Change	SE
DTG[1] (n=5)									
	60	99.00	101.00	0.62	0.28	92.60	101.40	7.13	3.19
	120	75.80	83.00	10.37	4.64	83.00	78.40	2.87	0.81
	300	51.00	57.60	14.34	6.41	52.80	56.20	5.79	2.59
	450	51.40	58.60	15.89	7.11	52.20	58.20	13.62	6.09
NDTG[2] (n=7)									
	60	137.43	142.86	4.58	1.73	137.29	133.71	-4.88	1.04
	120	111.57	113.14	1.94	0.73	115.00	112.71	-1.59	0.60
	300	77.00	81.29	6.21	2.38	75.14	78.86	5.11	1.93
	450	75.43	79.14	5.96	2.25	72.57	78.00	8.22	3.11
CG[3] (n=6)									
	60	122.50	118.17	-1.85	0.76	117.00	116.50	-0.67	0.27
	120	99.00	118.17	6.38	2.60	98.00	99.33	-0.21	0.09
	300	69.17	74.00	8.86	3.62	71.33	78.00	11.86	4.84
	450	70.17	79.67	14.36	5.86	70.00	79.33	14.17	5.78

[1] Dominant Training Group
[2] Non Dominant Training Group
[3] Control Group

change and the mean pre- and post-test scores. DTG registered concentric strength improvements in the trained leg of 15.89% $\pm$7.11 and 14.34% $\pm$6.41 at 450^o/sec and 300^o/sec repetitively. The percent changes for NDTG trained leg were 5.96% $\pm$2.25 at 450^o/sec and 6.21% $\pm$2.38 at 300^o/sec. The dominant leg of the CG demonstrated similar increases in the mean percent change for the high velocity speeds, which were 14.36% $\pm$5.86 and 8.86% $\pm$3.62 at 450^o/sec and 300^o/sec repetitively.

The untrained leg of the experimental groups and the non-dominant leg of the CG data demonstrated positive mean percent changes in high velocity concentric strength. Mean percent change increases at 450^o/sec were 13.62% $\pm$6.09 for DTG, 8.22 $\pm$3.11 for NDTG, and 14.17% $\pm$5.78 in the CG. At the 300^o/sec velocity mean percent change of concentric strength was also evident 5.79% $\pm$2.59 for DTG, 5.11% $\pm$1.93 for NDTG, and 11.86% $\pm$4.84 for the CG.

The data regarding the slow and moderate concentric velocities of 60^o and 120^o/sec demonstrates varying degrees of decline and/or gain in the mean percent change for the groups. DTG increased strength in the trained and untrained legs at 60 and 120^o/sec. NDTG demonstrated an increase in the mean percent change for the trained leg at both speeds, however, the untrained leg presented a negative percent change at the slow and moderate velocities. The CG also demonstrated positive and negative mean percent strength changes in the dominant and non-dominant legs.

Partial correlation coefficients of the eccentric training velocity and the percent change of the six velocities reinforced the trend regarding mode-speed specificity of the strength training. The eccentric velocity of 60^o/sec demonstrated a weak correlation of $r=.55$ ($p<.03$) to 120^o/sec eccentric training velocity. The partial correlation coefficients of mean percent change of the four concentric velocities are non-significant. The partial correlation coefficient data are presented in Table 5.

TABLE 5. PARTIAL CORRELATION COEFFICIENTS OF THE PERCENT CHANGE OF THE TEST VELOCITIES AND THE ECCENTRIC TRAINING VELOCITY

	Concentric				Eccentric	
Training Velocity	% Change 60^{o}/sec	% Change 120^{o}/sec	% Change 300^{o}/sec	% Change 450^{o}/sec	% Change 60^{o}/sec	% Change 120^{o}/sec
120^{o}/sec Eccentric	0.36	0.01	0.18	0.37	0.55*	1.00*

* Significant at $p<.03$

CHAPTER 5. DISCUSSION AND CONCLUSION

The specificity of strength training is a commonly accepted concept for athletics and in training and conditioning practices. Other mechanisms of the strength training design are also commonly accepted as specific. Isometric training is reported to increase force production at the training angle of the joint (MacDougall et al., 1979; Sale and MacDougall, 1981). Strength gains as a result of isotonic training are shown to be specific to isotonic strength and do not transfer to isokinetic force output (Thorstensson, Hulten, van Doblen, and Karlsson, 1976).

The specificity of the contraction type, either eccentric or concentric, is a determining factor in the success of a strength training program. Eccentric contractions are known to generate forces considerably greater than concentric contractions (Ghena, 1988; Davies, 1985). The present study observed a difference of 21.96 ft.lbs. of peak torque at the 60^{o}/sec velocity and 112.01 ft.lbs. at 120^{o}/sec for the eccentric force as compared to the concentric force of the three groups during the pre-test. Therefore, if force output is a factor in designing the strength training program, then eccentric contractions should be integrated into the program due to the increased force output generated. But with any strength training program, the training should be specific for the ultimate goal (Sale and MacDougall, 1981) as in the case of injury rehabilitation.

The improvements generated in eccentric force at 60 and 120^{o}/sec by the DTG and NDTG were non-significant. The percent change increase exemplified the more specific trends which were occurring between the eccentric velocities as a result of the eccentric training. This trend agrees with the results of Duncan et al. (1989), who report that isokinetic eccentric strength training at 120^{o}/sec was eccentric mode specific. Other studies (Colliander and Tesch, 1990; Ellenbecker et al., 1988) indicate that eccentric training is not mode specific. However, changes reported in the current study are related more to learning factors associated with isokinetic training rather then physiologic strength gains.

Changes in eccentric strength for untrained limbs were non-significant. The CG demonstrated a greater percent change of eccentric force for the non-dominant limb at 60 and 120^{o}/sec than either of the training groups (see Table 3). The lack of this transfer effect was reported previously by Jones and Rutherford (1986) from an observation of an isometric strength training program.

The percent changes of the concentric torque results (Table 4) demonstrate the variability which existed between the groups. The percent change for the four velocities ranged from 1 to 16% for the DTG, 2 to 6% for the NDTG and the CG ranged from -2 to 14%. The untrained limb was also extremely variable in percent change at the force velocities between and within the groups. These changes were related to the learning factor regarding isokinetic training.

The trends observed regarding eccentric strength training were probably negatively influenced by the duration of the study. The study occurred during the second block of a summer school session which created the time limitation allotment. The five-week block allowed for only three weeks of training after allocation of one week for pre-testing and one week for post-testing. The training studies reviewed in preparation for this current study allowed four to 18 weeks for training, which did not include pre- and post-testing periods. As a result, it would be reasonable to assume that only neural changes occurred as a result of the training.

The subjects were participating in a physical fitness concept class (Health and Wellness) simultaneously with participation in the study. The course requirements included attendance and participation in different types of exercise involving physical conditioning (run/walk/jog, swimming, and aerobic dance) and weight training (free weights and Nautilus equipment). The course also included pre- and post-tests regarding anthropometric composition, cardiovascular endurance (9-minute run), and maximum strength. The pre- and post-tests for the course occurred during the same time frame allowed for pre- and post-tests of the study. Subsequently, a fatigue problem was subjectively reported by several of the subjects.

The increases (non-significant) in eccentric strength observed in this study are important in the rehabilitation of injuries and for the prevention of injuries. The eccentric mechanism is an important factor in the daily locomotion patterns of humans, i.e. descending hills, stairs. The mild change in the eccentric strength occurred over a short period of three weeks. During this period the subjects who had acknowledged previous quadriceps weakness subjectively reported feeling stronger while playing tennis, jogging, etc., which indicates the importance of eccentric training for moderate physical activity.

Another aspect of the eccentric training program which was not analyzed was the vast improvement in total work ($watts \cdot m \cdot s^{-1}$) for the subjects. The range which the experimental subjects increased in mean total work was 44.5 to 104,540 $watts \cdot m \cdot s^{-1}$ during the three week training session. This increase in eccentric endurance indicates the reason for the subjects perceiving an increase in strength and thus reporting "feeling" stronger.

Conclusion

Several positive trends existed both within and between the training groups regarding changes in eccentric strength. The percent changes reported for the groups were non-significant. The speed effect of the training demonstrated significance. The training effect of the eccentric training velocity of 120^{o}/sec on the 60^{o}/sec was shown to be significant with a weak correlation of $r=.55$. However, the learning effect was an important factor regarding the mild percent change of eccentric and concentric strength for the three groups.

Much of the literature fails to address the nature of eccentric strength studies and the determination of the training effect in terms of eccentric strength. Other literature indicates that concentric strength training has an effect on eccentric strength. The application of the transfer of concentric to eccentric is a topic which needs to be explored, and additional eccentric strength studies of this nature are recommended.

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APPENDIX A

INFORMED CONSENT FORM FOR PARTICIPATION IN A STUDY ON A COMPARISON OF THE TRANSFER AFFECT OF ECCENTRIC ISOKINETIC STRENGTH TRAINING ON HIGH VELOCITY CONCENTRIC STRENGTH

I, ___________________________________, agree to participate in this research project which consists of an isokinetic strengthening protocol and a series of pre- and post-isokinetic quadriceps and hamstring strength tests. This study is conducted by Joel Cagle with the full approval of the Human Subjects Committees of Iowa State University and Northeast Missouri State University. I understand that an injury may occur during either the strength training program or testing portions of the study. I understand that participation in this study is totally voluntary, and I have the right to refuse to participate, withdraw from the study, or withdraw my data from the study at any time by contacting the researcher. I also understand the following:

The Purpose of the Study: The purpose of this study will be to determine the effect of concentric and eccentric isokinetic training on muscle strength.

The Procedure: The data collecting procedure requires the completion of a pre- and post-isokinetic strength test knee flexion and extension at 60^{o}, 120^{o}, 300^{o}, and 450^{o} per second concentrically and 60^{o} and 120^{o} per second eccentrically (resistance of the movement) by a Biodex dynamometer. The training procedure will consist of 9 training sessions for 3.5 weeks in two of ten repetitions at 120^{o}/second at 70% maximal contraction goal, as determined by the Bioware, in the eccentric mode. Training sessions and testing will be preceded by a five minute "warm-up" on the Monark ergometer. The training session procedure will require approximately 15 minutes per session, and testing procedures will require approximately 30 minutes per session. The subject will be able to discontinue the test or strengthening procedures by activating the stop button switch on top of the Biodex.

Confidentiality: The information provided by the procedures will be used only by the researcher, and all the participants will remain anonymous, thus assuring confidentiality. No information which identifies individuals participating in this research will be released to anyone.

Release From Liability: I understand musculoskeletal injury (e.g., muscle soreness, strain, tendonitis, or edema) may occur during either the testing or strengthening procedure. With this knowledge, I hereby release any and all members of the testing team, Athletic Department, Exercise Physiology Department, Division of Health and Exercise Science, and Northeast Missouri State University; and the research team, Athletic Department, Division of Physical Education and Leisure Studies, and Iowa State University from liability of injury as a result of the isokinetic workouts or testing.

Compensation for treatment of any injuries that may occur as a direct result of participation in this research may or may not be paid by Iowa State University depending on the Iowa Torts Claims Act. Claims for compensation will be handled by the Iowa State University Vice President for Business and Finance.

Voluntary Consent: I certify I have read the preceding information, or it has been read to me, and I understand its contents.

Any questions that I have pertaining to the proceeding have been and/or will be answered by the researcher. My signature below means that I fully agree to participate in this study.

* *

Signature: ________________________________ Date: ____________________

Witness: _________________________________ Date: ____________________