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Prediction of maximal isokinetic knee strength from submaximal measurements

Amanda J. Sinclair
San Jose State University

PREDICTION OF MAXIMAL ISOKINETIC KNEE STRENGTH FROM SUBMAXIMAL MEASUREMENTS

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Amanda J. Sinclair, ATC

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APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

Jack Ransone, Ph.D., ATC

Craig Cisar, Ph.D.

Emily H. Wughalter, Ed.D.

APPROVED FOR SAN JOSE STATE UNIVERSITY

Serena Stanford, Ph.D.

ABSTRACT

PREDICTION OF MAXIMAL ISOKINETIC KNEE STRENGTH
FROM SUBMAXIMAL MEASUREMENTS

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The purpose of this study was to determine the strongest combination of variables which predict maximal (30°/s) isokinetic knee strength using stepwise regression analyses. Male (n = 30) and female (n = 18) subjects aged 23.77 ± 1.78 years underwent isokinetic testing to determine quadricep and hamstring peak torque at 30, 60, 120, and 180°/s. Demographic data of age, body weight, and gender were also included as predictor variables. Strong correlations ($p < .01$) ranging from $r = .62$ to $r = .85$ were found between quadricep and hamstring peak torque at 30°/s and hamstring peak torque at 60, 120, and 180°/s. One-way ANOVA determined no significant ($p > .05$) difference between peak torque measurements and testing order. Stepwise multiple regression analyses revealed quadricep peak torque at 60°/s as the strongest predictor of quadricep peak torque at 30°/s ($R = .832$, $R^2 = .692$, SEE = 23.544). Hamstring peak torque at 60°/s best predicted hamstring peak torque at 30°/s ($R = .852$, $R^2 = .726$, SEE = 14.637).

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Chapter 1

INTRODUCTION

Strength training is used regularly by athletes and nonathletes to improve physical fitness and to provide foundation for enhanced performance levels. To determine the prescription for a strength training program, exercise testing is often performed in order to establish a physical baseline. The National Strength and Conditioning Association (NSCA) defines strength as the ability to exert a force. Strength is normally measured by the maximal amount of weight an individual can move in one repetition of a movement or in one isometric contraction (Baechle, 1994).

In 1955, Clarke and Herman began researching 10 repetition maximums (10RM) to determine if muscular strength could be objectively determined. They worked from a one repetition maximum (1RM) measurement and analyzed the percent of weight that could be lifted over 10 repetitions (Clarke & Herman, 1955). The Clarke and Herman study formed a basis for studies predicting 1RM at a submaximal level. It has been found that 1RM can be predicted from a multiple RM such as the number of repetitions performed in one minute at a given percentage of the 1RM (Kovi, 1992; Mayhew, Ball, & Bowen, 1992). A multiple RM measurement places less stress on the musculoskeletal system, therefore decreasing the individual's risk of injury. Using a multiple RM also shortens the amount of time needed for testing as well as the number of personnel (i.e., spotters) necessary to complete the task safely (Rose & Ball, 1992). Risk of injury may further be reduced by using isokinetic testing as an isokinetic dynamometer will compensate for the change in contractile speed of the muscle (Cybex Manual, 1983).

Strength training can be performed isometrically, isotonically, or isokinetically. Isometric exercises are mainly used in rehabilitation programs; but since in an isometric contraction joint angle remains stable, most functional aspects of movement are lost. Isotonic exercises are some of the most functional types of exercise, but a greater risk of injury exists since multiple joints and muscle groups are used during the movement. Another problem with isotonic exercise is the movement is not easily terminated. Functional aspects are sometimes reduced during isokinetic exercise, but are maximized when the exercise is administered correctly. Isokinetic exercise is performed using an isokinetic dynamometer which provides the ability to test strength with computer interface (Perrin, 1993). The Cybex Isokinetic Dynamometer (Division of Lumex, Ronkonkoma, New York) has been shown to be a reliable tool for determining muscle strength (Perrin, 1986).

Strength is one component of a sound rehabilitation protocol along with flexibility and endurance (Kisner & Colby, 1985). Post-injury or post-surgery, individuals undergoing rehabilitation are required to perform some type of strength testing in order to give a baseline measurement for their strength level. The key to this test for the clinician is administering the strength test without compromising the injury or healing process of the individual. One means of accomplishing this is by utilizing isokinetic exercise.

Isokinetic exercise is frequently used in rehabilitation protocols, but is often overlooked during strength testing for prescription purposes. Since risk of injury is less with isokinetic exercise than isotonic exercise (Cybex Manual, 1983), strength testing isokinetically could allow a safer option for an individual who is at a potentially high level of risk while permitting functional activity. To reduce risk of injury further than maximal isokinetic measurements, isokinetic strength testing could possibly be done in a manner similar to isotonic strength testing by predicting 1RM from multiple RM. In other words, combining the safety of isokinetic testing with submaximal repetitions to predict maximal knee strength from submaximal strength.

Statement of Problem

The purpose of this study was to determine the strongest combination of variables which best predicted maximal (30°/s) isokinetic knee strength through stepwise regression analysis.

Delimitations

Certain delimitations were set by the investigator of this study which may have affected the results and conclusions drawn. The following delimitations were acknowledged:

1. Healthy college age students served as subjects due to the availability of this population and the lack of available adolescent and elderly populations.
2. Testing was completed on an isokinetic dynamometer due to the availability of equipment and reliability and validity of the isokinetic dynamometer as compared to isotonic and isometric testing measurements (Cordova, Ingersoll, Kovaleski, & Knight, 1995; Perrin, 1986; Perrin, 1993). Isokinetic testing has greater control for standardized implementation of the measurement unlike isometric and isotonic movement.

3. Due to time constraints, isokinetic strength testing was conducted for the quadricep and hamstring muscle groups of the dominant leg only.
4. Velocities used during the isokinetic testing were 30, 60, 120, and 180°/s. Maximal isokinetic strength was represented by 30°/s. The velocities of 60°/s and 180°/s are routinely used for isokinetic strength measurement (Gross, McGrain, Demilio, & Plyler, 1989; Keskula, Dowling, Davis, Finley, & Dell'Omo, 1995). In order to have a third variable within the confines of strength, not endurance, 120°/s was also used (Emery, Sitler, & Ryan, 1994). This was aimed to avoid increases in quadricep fatigue seen at higher velocities and to avoid movements that are endurance related. Strength is normally represented by measurements between 0°/s and 180°/s (Cybex Manual, 1983).

Limitations

The limitations set in this study reflect the effect of the delimitations on the collection and interpretation of the data and the ability to expand the scope of inference beyond the sample population. Generalizations made from the results will be compromised by the following limitations:

1. Inferences cannot be made outside of the tested populations. Generalizations to pediatric and geriatric populations can not be established. However, they may be placed on reconstructed anterior cruciate ligament (ACL) injured populations as no difference is seen with stresses placed on the graft due to the difference in structure and decreased elasticity of the graft as compared to injured ligament tissue (Buchanan, Kegerreis, & Smith, 1991). The acquisition of subjects from a group of volunteers and not by random sampling prevents inferences beyond the

study sample.

2. No inferences can be made to isotonic and isometric testing because they involve different kinesiological factors than isokinetic contractions. Neither isotonic nor isometric movement involves a constant velocity as isokinetic movement does. Isometric movements do not have a change in joint angle, and isotonic movements often occur in more than one plane and with more than one muscle group (Perrin, 1993). Isokinetic exercise can provide improvement for functional tasks better than isotonic movements for the involved joint (Cordova, Ingersoll, Kovaleski, & Knight, 1995). Isotonic and isometric testing may demonstrate significant differences in results, so particular caution should be taken in generalizing results beyond this study.
3. Results of this study will only be applicable to the quadriceps and hamstring strength of an individual as other muscle groups respond differently to the isokinetic movement (Cybex Manual, 1983; Perrin, 1993). The level of work output by each subject is dependent on the degree of motivation and willingness to give maximal effort throughout the testing procedure.
4. Predictions can only be made from the three velocities used during the strength testing since differences in endurance and fatigue are seen at other velocities (Emery, Sitler, & Ryan, 1994). Other velocities of isokinetics may elicit different results, and caution should be taken when making inferences to other test velocities.

Assumptions

The following statements were assumed true when analyzing the results of the study:

1. The subjects were healthy based on the general history taken prior to testing and the information received on the health and demographic questionnaire being honest and accurate.
2. The subjects put forth maximal effort and followed instructions as given. The warm-up allotted for each subject was sufficient to allow maximal effort in all phases of the testing.
3. The investigator's attitude and assistance were not biased towards a particular individual or testing order.

Hypotheses

1. Maximal knee strength will not be significantly predicted from the predictor variables of 60, 120, and 180°/s, gender, age, and weight.
2. There will not be a significant difference between testing order and peak torque measurements of the knee.

Significance of the Study

Maximum repetition strength testing has been used regularly to determine one's strength level and to develop rehabilitation or regular exercise protocols. Strength testing is included in many physical fitness assessments to improve the reliability of those assessments (Rose & Ball, 1992). In each situation, safety is always a concern. A regression equation could allow a much safer testing protocol than is offered now in rehabilitation and physical fitness.

The use of isokinetics has shown to have a low risk of injury during strength testing (Cybex Manual, 1983). An isokinetic test is often required after a knee reconstruction for insurance purposes. Therefore, the importance of this study was to develop a regression equation that predicted maximal strength from a submaximal level to provide an effective way to determine 1RM for an individual who should not be placed at risk for an injury. A prediction equation could help protect post-surgical knees by reducing shearing forces and by improving the safety of strength testing (Buchanan, Keggereis, & Smith, 1991).

Definition of Terms

Dynamometer -- A device used for measuring muscular strength (Taber, 1993). For example, an isokinetic dynamometer measures torque of angular movement. In this study, the Cybex II+ isokinetic dynamometer was used to measure knee strength.

Hamstring -- Refers to the muscle group that includes the following three muscles: semitendinosus, semimembranosus, and biceps femoris (Hoppenfeld, 1976). In this study, the hamstring group may also be abbreviated as the ham when necessary.

Isokinetic contraction -- The production of force and angular movement against a fixed velocity. Maximum effort can be put forth throughout the joint range of motion. Movement is voluntary, so it can be abandoned at any time to prevent injury (Perrin, 1993). Isokinetic peak torque was measured at four velocities for this study.

Isometric contraction -- The ability to produce a static force without a change in joint angle. It is isolated to a specific muscle group within limits of range of motion. It can be used to measure strength of a muscle group that is cast or braced (Perrin, 1993). Isometric contractions were only used for comparisons to isokinetic contractions in this study.

Isotonic contraction -- A dynamic movement throughout a joint range of motion. Velocity cannot be controlled, multiple muscle groups/joints can be involved, and concentric and eccentric contractions are combined. The range of motion in isotonic contractions is only limited by the weakest point in the movement (Perrin, 1993). Isotonic contractions were only used for comparisons to isokinetic contractions in this study.

Peak torque -- The point during movement around a joint axis that the greatest amount of force is reached. It is measured as the magnitude of force multiplied by the length of the lever arm (Baechle, 1994). For this study, peak torque was recorded for maximal effort repetitions at four testing velocities and was labeled with ft/lb. It was abbreviated as PT in this study.

Quadricep -- Refers to the muscle group that includes the following four muscles: vastus medialis, vastus intermedius, vastus lateralis, and rectus femoris (Hoppenfeld, 1976). In this study, the quadricep group was abbreviated as the quad.

Chapter 2

REVIEW OF LITERATURE

Strength measurement has become an integral aspect of prescribing exercise and rehabilitation protocols for physical fitness and athletics. Many studies have emerged as strength training has gained popularity. These studies focus on many different factors involved with strength training, such as maximal effort, reliability, and standardized protocol. Through the following literature review, information concerning repetition maximums, the reliability of isokinetic exercise, and effects on isokinetic measurement will be presented.

Repetition Maximum

Prior to the study conducted by Clarke and Herman in 1955, subjective measurement of a load used during 10RM was used. Clarke and Herman intended to objectively determine weight percentage used for 10RM. Through their analysis of the right and left quadriceps of 30 military personnel, they determined that loads of 50% maximum could objectively represent 10RM. Before testing, the subjects were examined for knee extension competence. Subjects performed knee extensions on a cable tensiometer with the knee starting in 135° extension. Subjects wore a specially designed boot while performing resistive exercises of repetitions to fatigue of the quadriceps. Five percentages--30, 35, 40, 45, and 50%--were used during five sessions with each subject. Following the resistive phase, a final strength test concluded testing. The right and left legs displayed similar linear declines in repetitions as percentage of weight increased. Standard error of difference was measured at 5.62 lb. Correlation between 30 and 50% was .38 and between 45% and 50% was .55.

Clarke and Irving (1960) replicated the Clarke and Herman (1955) study but examined the right hamstring group of 28 college students. After a beginning strength test, subjects executed resistive knee flexion exercises at percentages of 40, 45, 50, and 55 using repetitions to fatigue. Clarke and Irving rotated percentages to eliminate learning effects, and means for each velocity were reported. The results showed declining repetitions in a near linear pattern. Comparisons with the quadriceps results showed the greatest differences during lower percentage loads. The load of 55% had the best relationship with 10RM for the hamstrings. Clarke and Irving determined that there is a negative 15% difference between the quadricep and hamstring muscle groups. This study along with the Clarke and Herman study initiated further research for load percentage determining 1RM.

Strength testing, mainly bench press strength (an isotonic exercise), has been the focus of many studies observing the predictive capabilities of percentages or multiple repetitions. One such study by Rose and Ball (1992) included 84 untrained collegiate females, ranging in age from 18-25 years. Rose and Ball used absolute muscular bench press endurance measured with the YMCA bench press test to predict 1RM bench press of the females. Determination of 1RM was accomplished after a 10 repetition warm-up. The investigators increased weight at increments of 2.3 to 4.5 kg. until only one repetition could be performed, allowing three minutes of rest between weights. Rose and Ball found high intraclass correlations of .98 for bench press and .97 for absolute endurance. Through a stepwise regression analysis using body weight and muscular endurance, Rose and Ball concluded that absolute muscular endurance is a good predictor of 1RM bench press. Cross validation through a sub-sample indicated a high bench press prediction correlation of .82. However, their results cannot be generalized to males due to their exclusion from the study.

Mayhew, Ball, and Bowen (1992) addressed the issue of gender in a similar study by including 70 males and 101 females from a college fitness class in their test group. They intended to use submaximal bench press efforts to predict maximal bench press loads. Olympic bench press lifts performed by each subject helped to determine their 1RM. Mayhew et al. randomly assigned each subject to a percentage between 55% and 95% of their 1RM to lift as many times as possible within one minute. The subjects performed repetitions to fatigue a second time after a 14 week resistance and aerobic training program. Men increased bench press strength by 13.7% while women improved by 25.9%. The number of repetitions lifted in one minute did not significantly differ when comparing pre- and post-tests. Predicted bench press and actual bench press strengths were not significantly different. Correlation for actual bench press from predicted strength was .90 for males and females. The conclusion drawn was that submaximal bench press effort could effectively predict 1RM bench press for both males and females.

Hoeger, Hopkins, Barette, and Hale (1990) completed a study which opposed the method of standardized percentages for strength protocols which was commonly used. In their study of untrained subjects, 38 male and 40 females, and trained subjects, 25 males and 26 females, they observed the difference in repetitions of percentage of 1RM between groups. Each subject determined his/her 1RM of arm curl, knee extension, bench press, sit-up, leg curl, lat pulldown, and leg press on a Universal machine. Repetitions to fatigue testing were performed at percentages of 40, 60, and 80 with 1 1/2 to 2 minute rests between lifts. Hoeger et al. ran multiple analyses of variance and found reliability was highest for male knee extension and leg curls, reported at .94 and .98 respectively for an 80% load. For females, knee extension reliability measured highest at 40% load at .96, while highest reliability for leg curls, .86, appeared at the 80% load level. Repetitions at each percentage varied among the entire population, which suggested standardized repetitions may not resemble the same percent of 1RM for each type of lift examined. Inferences can be made that training protocols are not accurately assigning repetitions (percentages) to lifts.

The ability to predict isokinetic knee torque from stepwise regression equations including anthropometric data was examined by Gross, McGrain, et al. (1989). Significant results were found with the 70 female and 64 male subject group, whose ages ranged from 10 to 80 years. One equation was written including test velocity, age^2, sex, height, weight, thigh girth, and percent body fat for measurements pre- and post-injury. The second equation used only age^2, sex, height and weight for measurements taken only post-injury. Subjects performed isokinetic testing using a Cybex II dynamometer at 60°/s and 180°/s. Subjects executed 5 submaximal repetitions, a 2 minute rest, and then 3 maximal repetitions. Next, the subjects repeated the rest and maximal efforts. Gross, McGrain, et al. reported the multiple correlation at .78-.87, which indicated that the equations used in this study could be used to determine strength.

The study by Gross, McGrain, et al. (1989) was followed up by Gross, Credle, Hopkins, and Kollins (1990). Twenty-three females and 15 males, ages 10 to 77 years, participated in the study using the same protocol as Gross, McGrain, et al. Pearson product moment correlations and absolute difference between torque values were calculated. Post hoc analysis consisted of combining the original group from the Gross, McGrain, et al. study and the new group added by Gross, Credle, et al., running the regression analysis and determining absolute error among torque values. Results indicated a .7% variation between the two equations, an absolute error of predicted torque of 12.8 ft./lb., and a test-retest reliability of .93. Gross, Credle, et al. concurred with the results found in the original study.

Cross validation of the 1989 Gross, McGrain, et al. study was completed by Housh et al. (1994). Forty-three men, ages 19 to 36, comprised the sample group for the cross validation. Housh et al. gave instructions for isokinetic testing to the subjects during a practice session. The test followed 24 hours later, following the protocol set by Gross, McGrain, et al. The subjects performed a 4 minute warm-up on a stationary bicycle. Statistically, the analysis was composed of the analysis from the 1989 study and procedures for cross validation that included mean difference (flexion 15.7 to 29.7 ft/lb; extension -7.6 to 3.1 ft/lb), standard error of estimate (flexion SEE = 13.1 to 15.2 ft/lb; extension SEE = 21.3 to 24.6 ft/lb), validity coefficient (r = .55 to .72), and paired t-tests. Housh et al. found that the two equations worked best for subjects whose peak torque was closer to the mean peak torque of the original Gross, McGrain, et al. study. The conclusions infer that since the original sample was more heterogeneous than the group in this study, the equations may not be generalized to specific age groups.

Reliability of Isokinetics

Isokinetic dynamometers are used for strength testing for which high reliability has been reported. Perrin (1986) reported reliability of knee extension peak torque measurements on a Cybex dynamometer at .84-.93 from a study using 15 males with a mean age of 20.53 years. Perrin used test velocities of 60°/s for maximal strength (5 repetitions) and 180°/s for maximal endurance (25 repetitions) in this study. Pearson product moment correlations were found for peak torque, torque acceleration, endurance, average power, and total work. Comparisons of knee peak torque to shoulder internal/external rotation and shoulder flexion/extension tests indicated that the knee had higher reliability coefficients overall than either of the shoulder tests.

Kramer (1990) reviewed previous studies on concentric knee extension, concentric extension/flexion cycles and eccentric-concentric cycles, all of which reported good reliability for each type of isokinetic testing. He also found reliable torque measurements for eccentric-concentric cycles for a group of 20 females and 15 males. Peak torque and average torque were measured at 45°/s and 90°/s for this study. Subjects executed three eccentric-concentric cycles with no rest during three sessions. Peak torque correlations ranged from .79 to .91 while average torque correlations ranged from .75 to .88. Kramer concluded that reliable torque measurement can be received when using three submaximal contractions and one maximal contraction for practice prior to performing the maximal exercise.

Not only is reliability of the isokinetic dynamometer important, but so is reliability among test administrators. Keskula, Dowling, Davis, Finley, and Dell'Omo (1995) examined the interrater reliability for isokinetic testing. Four raters tested 8 men and 8 women using a Cybex 6000 to measure peak torque and total work load of concentric knee flexion and extension. Subjects were randomly assigned to a rater then tested at 60°/s and 180°/s. Keskula et al. noted the variations in subject position and adjusted scores for gravity. They figured intraclass correlation coefficients (ICC) for peak torque and work load for each subject on data gathered from the four raters and again for two testing conditions (muscle group and test speed). ICC for peak torque ranged from .90-.96 and .90-.95 for total work. Standard error of measurement procedures resulted in 8.9-13.3 Nm for peak torque. Keskula et al. concluded that four raters can achieve reliable measures of isokinetic testing of concentric knee flexion and extension.

The reliability of isokinetic measures can also be affected by other extrinsic factors such as gravity. Testing protocols frequently include correction for gravity effects. Nelson and Duncan (1983) found that by not correcting for gravity effects, measurement error of 4% for knee extensor measurements and 15% for knee flexor measurements would be present. Their method for correction began by calibrating a Cybex II dynamometer according to the corresponding manual and velocity set at 30°/s. With a subject positioned correctly in the Cybex and the knee at full extension, the tester holds the lever and releases it with the subject relaxed. Passive torque measurements and angle for the measurement are then placed into the correction formula. Nelson and Duncan believe that this method will reduce the gravity effects of the measurement; however, computer interfaces for isokinetic dynamometers will automatically correct for gravity.

Effects on Isokinetic Measurement

Clarke and Manning (1985) studied 18 males, ages 20-28 years, performing isokinetic repetitions to fatigue at 120°/s, 160°/s, and 200°/s on a Cybex II dynamometer. They found peak torque declines with an increase in isokinetic velocity. Peak torque was significantly higher during the first 50 to 60 seconds for repetitions at 120°/s. Examination found similarities in the curvilinear shape of the results for each velocity. Clarke and Manning concluded that the curved shape of the decline had no relation to the velocity.

Emery, Sitler, and Ryan (1994) also examined the amount of fatigue occurring during isokinetic testing using 12 healthy subjects, 6 men and 6 women, with a mean age of 20.6 years. Six sessions were allotted each subject with sessions 1, 2, 4, and 5 used for pretesting. A Biodex B-2000 isokinetic dynamometer was used with blocks at 10° and 90° flexion. Subjects performed five submaximal repetitions followed by rest and 5 maximal repetitions at 50% of peak torque prior to the repetitions to fatigue. Following analysis of variance, Emery et al. noted that concentric muscle fatigue is greater at 60°/s than at 150°/s due to greater energy demands to the muscle complex. In this study, the hamstring group fatigued prior to the quadriceps group. Both this study and the Clarke and Manning (1985) study indicate that endurance rather than strength becomes more of a factor of isokinetic measurement as velocity increases.

Perkins, Taunton, Rhodes, and Clement (1994) studied knee flexion, extension, and the corresponding ratios during isokinetic exercise. Seventytwo healthy males, ages 18-35 years, were divided into three groups: power athlete, aerobically trained runner, and moderately active individual. Subjects executed concentric and eccentric repetitions at 90°/s, 135°/s, and 180°/s in the supine position on a Kin-Com dynamometer. Each subject performed 5 repetitions, three submaximal and two maximal, followed by a 3 minute rest. Perkins et al. truncated measurements between 75° and 30° of flexion. The power athlete group had greater torque measures for both contractions as compared to the other two groups. The power athlete group also had the highest concentric-eccentric ratios. Concentric torque for both flexion and extension declined as velocity increased. Eccentric average torque remained steady for all groups. Perkins, et al. concluded that moderately active individuals and aerobically trained individuals react similarly to isokinetic exercise.

Most studies involved a rest period between sets, but Stratford, Bruulsema, Maxwell, Black, and Harding (1990) examined the effect that rest has on the measurement. They compared knee flexion and extension torque measurements at 60°/s on an isokinetic dynamometer. Two groups each performed in five sessions, one group with no rest, the other with 30 second rest between sessions. A 5% difference was seen between the two groups with the rest group having higher average torque. Stratford et al. noted less measurement error with average torque measurements than peak torque measurements. They concluded that more accurate isokinetic measurements would be achieved when using a rest period during testing.

Hoens and Strauss (1994) examined yet another source of measurement error--acceleration/deceleration (nonisokinetic) phases. After studying 72 men and women, ages 20 to 70 years, they concluded that a greater amount of the range of motion is nonisokinetic as velocity increases. Hoens and Strauss examined trunk extension and flexion as tested on each subject on a Kin-Com dynamometer in the erect sitting position. One week prior to testing, each subject underwent one learning session. Velocities used during testing were 20°/s, 40°/s, and 60°/s. Subjects performed three submaximal trials and then maximal repetitions until the proper torque curve was elicited. Hoens and Strauss corrected for gravity prior to testing. Measurements were taken with and without trimming the measurement for nonisokinetic phases. If there were unequal variances between scores, ANOVA was run; otherwise, they used paired t-tests. At 20°/s there was no significant difference between regular and truncated measurements; however, at 40°/s and 60°/s significant differences were found. Hoens and Strauss reported that the acceleration and deceleration affect average torque measurements more significantly than peak torque. They suggested that measurements be adjusted for average torque unless the results are for agonist/antagonist ratio measurements.

The response of ligamentous structures, mainly the anterior cruciate ligament (ACL), is a concern during isokinetic testing. In 1991, Buchanan, Kegerreis, and Smith executed a study examining the degree of anterior knee laxity associated with isokinetic exercise. Eight females and 20 males performed four maximal repetitions at 60°/s and 240°/s on a Cybex dynamometer. Buchanan et al. took laxity measurements with a KT-1000 arthrometer at the 20 lb force level. Testing occurred at an average of 19.1 months post-injury and an average of 7.6 months post-surgery. The results showed that reconstructed ACL knees had significantly less active quadriceps displacement than nonreconstructed ACL injured knees. Pre- and post-laxity measurements (mean difference = 0.5 mm) showed significant differences for ACL laxity as observed through paired t-tests. Buchanan et al. suggested that laxity readings be done post exercise for accuracy. These results indicate that individuals with ACL reconstructed knees can undergo isokinetic exercise and not be concerned with shearing forces to the joint.

Gross, McGrain, et al. (1989) used anthropometric data in their prediction equation which appeared to have some effect on the outcome of their study. Mayhew, Piper, and Ware (1993) found correlations between anthropometric data and isolated isotonic strength movements in a study using 58 college football players. Body mass index, standing height, sitting height, three muscle circumferences, and six skinfold measurements comprised the anthropometric data set for each subject. Subjects performed bench press lifts, squats, and deadlifts to determine strength. Variance in lifts was explained by coefficients of determination. Mayhew, Piper, et al. concluded that a relationship exists between the anthropometric data used and strength of resistance trained athletes. They also noted that large thigh girth did not always indicate good performance in the leg lifts.

Summary

The concept of multiple repetition maximum, or percent of 1RM, is regularly used during strength training even though there are opposing viewpoints. Hoeger et al. (1990) presented their conclusion that percentages cannot be assigned for all lifts in the same way. It appears, though, that many studies only utilize one lift in their protocol and that the percent of 1RM is determined prior to investigation that will eliminate the standardized percentage (Mayhew, Ball, and Bowen, 1992; Rose and Ball, 1992).

Anthropometric data has been used in several predictive studies such as Gross, McGrain, et al. (1989); Mayhew, Piper, et al. (1993); and Rose and Ball (1992). However, each set of data used was different, therefore, each result was different. As Gross, McGrain, et al. pointed out, different results occurred between their equations when thigh girth and percent body fat were removed from the data. This indicates that the anthropometric variables may not demonstrate the largest effect on the strength measurement. The Gross, McGrain, et al. study only utilized one isokinetic measurement as a predictive variable. If additional velocities are used in conjunction with age, weight, and gender data, the value of prediction may be stronger. Therefore, this study will use three isokinetic velocities and demographic data for predicting maximal isokinetic strength.

Although there are some opposing conclusions drawn regarding the reliability of isokinetic testing, overall it is reported as a reliable method of testing strength. The dynamometer and the measurement reliability both affect the outcome of the results. By acknowledging the factors that can affect isokinetic testing, attempts to eliminate the error can be more successful. The reliability of knee torque measurements from isokinetic dynamometers appears to be indisputably good, even with a change in raters (Keskula, Dowling, Davis, Finley, & Dell'Omo, 1995; Kramer, 1990; Perrin, 1986). Standardized protocols and correction for gravity have been accepted by researchers and are commonly used in research studies. Gravity correction can be important when performing isokinetic testing in a gravity-dependent plane and when making bilateral comparisons (Nelson & Duncan, 1983; Perrin, 1993). By understanding the calibration of the equipment and performing a few adjustments in the measurement procedures, reliable isokinetic results can be determined.

Fatigue seems to have the greatest effects on isokinetic measurements. As seen by Clarke and Manning (1985) and Emery et al. (1994), fatigue increases as velocity increases. An inverse relationship is seen in torque measurements as velocity increases (Perkins, Taunton, Rhodes, & Clement, 1994). Obviously, the conclusion can then be drawn that fatigue has an effect on torque by diminishing torque measurements. This may help explain the results found by Stratford et al. (1990) which indicated that isokinetic bouts with rest were more accurate than without. Rest would help to deter fatigue thereby preventing a decline in torque.

The effect of shear forces on the knee due to isokinetic exercise can be prevented with the use of anti-shear devices that can be placed on the lever arm of the dynamometer (Cybex Manual, 1983). According to Buchanan et al. (1991), these types of anti-shear devices may only be necessary for individuals who have injured their ACL and not undergone reconstruction. The safety of individuals who have had reconstructive surgery will not be compromised during an isokinetic exercise. Further investigation into this area and the anthropometric data relationship with prediction of strength would help to improve the reliability of test protocols and prediction.

Chapter 3

PROCEDURES

Strength testing is a common occurrence in physical fitness and rehabilitation protocols and is accomplished by various means, for instance, isokinetic testing. Isokinetic testing provides a means for determining strength with a decreased risk of injury (Rose & Ball, 1992). In order to reduce risk further, submaximal isokinetic strength testing could serve as an alternative route of testing. The object of this study was to determine the strongest combination of variables which would best predict maximal (30°/s) isokinetic knee strength through stepwise regression analysis.

Subjects

Subjects used in this study were 48 healthy college-age (18-28 years) male and female students. In accordance with the American College of Sports Medicine (1995), individuals within this age range did not need to have a prior exercise test and a physician did not need to be present during testing. The sample size was chosen to have an appropriate number of subjects per variable used in the regression analyses (Jackson, 1984). The subjects volunteered to be a part of the study, thus, not randomly sampled.

Instrumentation

Testing was completed on a Cybex II+ isokinetic dynamometer. Line drawing data was printed using the Cybex II dual channel recorder. Peak torque measurements were calculated with the Cybex II Chart Data Card (Appendix A) 180 and 360 ft/lb, 150° scales (Division of Lumex, Ronkonkoma, New York). Damping of the Cybex II+ was set at 2, according to the Cybex manual (1983) for strength testing. A hand held goniometer was used to measure knee range of motion. A platform scale was used to assess weight of the subject. Stationary cycling was performed on a Monark bicycle.

<u>Methodology</u>

The study was predictive in nature using three submaximal isokinetic strength tests and demographic data as predictor variables and a maximal isokinetic strength test as the criterion variable. Testing protocol had been designed based on recommendations by Davies in the *Compendium of Isokinetics in Clinical Usage* (1992). Determination of strength testing was based on research in the area of multiple repetition maximums (Gross, McGrain, Demilio, & Plyler, 1989; Mayhew, Ball, & Bowen, 1992; Rose & Ball, 1992).

An attempt was made to ensure that the results were not influenced by factors other than the independent variables. Perrin (1993) suggests that gravity correction should be done if reliable means are available. Gravity measurements in this study were not reliable, so correction was not calculated. As gravity was a constant for all subjects and bilateral comparisons were not necessary, the results of the study should not have been greatly affected. Testing velocities were randomly assigned, and standardized testing procedures were followed for each subject to improve internal validity. The ability to generalize from the results of this study was limited by several factors such as subject age and instrument type. The control of treatment protocol was necessary; therefore, the generalizability will only be valid under similar circumstances.

Prior to testing, subjects were issued an informed consent form and advised of any risks and benefits involved in the study (Appendix B).

Permission to conduct the study was granted by the Institutional Review Board at San Jose State University. Subjects selected a testing time during a three week period and were requested to wear shorts to the session. Subjects were then screened as to whether they were physically healthy and had not sustained injury to the test leg during the two months prior to the study (Appendix C). The subjects were questioned about other pre-existing conditions that would have been cause for elimination such as chronic or acute sprains/strains, effusion, and limited range of motion (Davies, 1992). Demographic information of age, weight, and gender of each subject was gathered; and each subject given an identification number for confidentiality purposes (Appendix D). All forms which can identify subjects were kept in the investigator's locked file cabinet and destroyed at the conclusion of the study.

Dominant leg was used for testing and determined by asking the subject "If I were to place a ball on the ground, which foot would you use to kick it?" (Cordova, Ingersoll, Kovaleski, & Knight, 1995; Gross, McGrain, Demilio, & Plyler, 1989). Measurements of the dominant leg for normal range of knee flexion of 135° and extension of 0° were taken using a handheld goniometer (Hoppenfeld, 1976). The subject performed quadricep and hamstring stretches two times for 30 seconds each (Baechle, 1994). Each subject warmed-up on a Monark stationary bike for 4 minutes before isokinetic testing (Housh, Housh, Weir, Stout, Weir, & Johnson, 1994). Each subject then drew one of the six possible orders of submaximal velocities from a stack of cards, each having one possible order written on it. A maximum of eight subjects per order were tested. Once eight subjects used a given order, that specific order was removed from the pile of cards.

Calibrations prior to testing and all testing sessions were completed by a certified athletic trainer experienced in isokinetic testing. The subject was positioned on the Cybex II+ in accordance with the Cybex II manual (1983). The subject sat in the seat of the Cybex II+ as far back as possible with knees flexed to 90°. Spacer pads were added if the subject's back was not firmly against the backrest of the seat. Subjects were asked to grasp the sides of the seat during testing. The shin pads, placed just proximal to the malleoli, and thigh pads were strapped as tightly as possible without compromising comfort of the subject. A torso strap was placed on the subject to eliminate any rocking motion of the torso. The axis of the knee was set at the femoral condyle.

The investigator read instructions for the isokinetic testing to each subject from a written script (Appendix E) to ensure each received equal instruction. Subjects were instructed to push and pull when performing test repetitions. The investigator notified the subject when the subject was on repetition three with the statement "maximal effort." This statement indicated that the next five repetitions were to be completed at maximal effort. Notification was also given during the eighth repetition stating "submaximal," indicating that only two submaximal repetitions remained. Each subject was instructed to terminate movement if any pain was felt. Three initial submaximal warm-up repetitions at each velocity were done to adjust subject position, if necessary, and allowed the subject to become accustomed to the dynamometer and flexibility of the joint (Housh, Housh, Weir, Stout, Weir, & Johnson, 1994). These repetitions were followed by a 3 minute rest (Rose & Ball, 1992). If during the warm-up repetitions it appeared that the individual would measure greater than 180 ft/lb, the scale was changed to the 360 ft/lb scale.

Maximal strength testing was completed first using the maximal velocity of 30°/s followed by a 5 minute rest. Repetitions were performed continuously in the order of three submaximal familiarization repetitions, five maximal effort repetitions, and two submaximal finishing repetitions. The continuous manner of repetitions was intended to eliminate startup patterns and abrupt stopping to ensure maximal effort for peak torque during the repetitions for analysis (Perrin, 1986). The same pattern of repetitions used at 30°/s were used for the first submaximal velocity. After a 3 minute rest, the same procedure was conducted at the second and third velocity settings. Another 3 minute rest period was given prior to the third test velocity. Peak torque data was collected from repetitions 4 through 8 and recorded on a variable report form (Appendix F).

Statistical Analyses

Statistical analyses were computed using Statistical Package for the Social Sciences (SPSS) (Statistical Package for the Social Sciences, Inc.). Descriptions of central tendency regarding the subjects' demographic information gathered was reported. Independent t-tests differentiated between gender and test variables. The highest peak torque value for each subject at each test velocity was reported (Appendix F). A one-way repeated measure ANOVA of the combination of submaximal velocities was run to determine if there was an order effect.

Stepwise multiple regression analyses were conducted to determine the strongest predictor(s) of maximal isokinetic strength from any combination of the three submaximal velocities tested and the demographic data. Forward multiple regression analyses were conducted to develop prediction equations using the variables in this study. The highest quadricep and hamstring peak torque values (ft/lb) from repetitions 4 through 8 during isokinetic testing were used for the analyses. The criterion variable was maximal strength (peak torque) measured at 30°/s. Predictor variables were submaximal strength (peak torque) at 60, 120, and 180°/s and demographic data of age, weight, and gender. Coefficients of multiple correlation ($\underline{R}$) and a coefficients of multiple determination ($\underline{R}^2$) described the variance throughout the regression analysis. Standard error of estimate was then calculated to examine the amount of predictive error. The alpha level of statistical significance was set at $\underline{p} \leq .05$.

Summary

The intent of this study was to determine if submaximal isokinetic strength measurements could be used to predict maximal isokinetic strength value of a given individual, and to determine if there was an order effect. Measurement of peak torque at 30°/s represented the criterion variable in this study while the predictor variables were peak torque measurements at 60, 120, and 180°/s and demographic data of age, weight, and gender. Statistical analysis using stepwise and forward regression analyses through SPSS was completed. Correlations among related data was also examined to help draw appropriate conclusions.

Chapter 4

RESULTS

This investigation assessed the strongest combination of variables for predicting maximal (30°/s) isokinetic knee strength through stepwise multiple regression analyses. This chapter will examine the results of central tendency on the descriptive data of the subjects, correlation coefficients related to the variables used in the regression analyses, analyses of variance examining the effect of test velocities by test order, and the results of the multiple regression analyses for determining peak torque at 30°/s.

Analyses of Descriptive Data

Descriptive statistics of mean (M), range, and standard deviation (SD) were calculated for the 48 subjects as a group and by gender. The subjects were males and females between the ages of 20 to 28 years. The mean age of the entire group was 23.77 years (± 1.78) and mean body weight was 171.38 lb (± 30.37). The analyses for characteristics of dominant leg peak torque at 30, 60, 120, and 180°/s along with age and body weight are reported in Table 1. Each subject randomly selected one of four treatment orders of testing velocities. The mean (± SD) peak torques for the quadricep and hamstring at 30°/s for the entire group were 148.56 ft/lb (± 41.98) and 88.13 ft/lb (± 27.68), respectively. Mean peak torque measurements for the quadricep and hamstring at 60°/s were 136.90 ft/lb (± 39.16) and 87.90 ft/lb (± 27.37), respectively. At 120°/s, the mean quadricep and hamstring peak torque measured 112.60 ft/lb (± 33.90) and 74.92 ft/lb (± 25.77), respectively. Finally, at 180°/s, mean quadricep and hamstring peak torque were measured at 90.10 ft/lb (± 33.47) and 64.60 ft/lb (± 25.46), respectively. The standard deviations of the measurements at all

Table 1

Descriptive Characteristics and Gender Comparison of the Subjects

Characteristics	Total Group	Females	Males	t-value
	N = 48	n = 18	n = 30	
PT Quadricep 30°/s (ft/lb)	148.56 ± 41.98	121.28 ± 28.21	164.93 ± 40.63	4.01*
PT Hamstring 30°/s (ft/lb)	88.13 ± 27.68	68.89 ± 19.95	99.67 ± 25.31	4.40*
PT Quadricep 60°/s (ft/lb)	136.56 ± 39.16	106.06 ± 27.57	154.87 ± 33.39	5.22*
PT Hamstring 60°/s (ft/lb)	87.90 ± 27.37	66.67 ± 18.63	100.63 ± 23.74	5.18*
PT Quadricep 120°/s (ft/lb)	112.60 ± 33.90	83.94 ± 18.89	129.80 ± 28.94	5.99*
PT Hamstring 120°/s (ft/lb)	74.92 ± 25.77	54.67 ± 16.22	87.07 ± 22.68	5.29*
PT Quadricep 180°/s (ft/lb)	90.10 ± 33.47	64.61 ± 19.70	105.40 ± 30.70	5.04*
PT Hamstring 180°/s (ft/lb)	64.60 ± 25.46	47.78 ± 18.81	74.70 ± 23.70	4.10*
Age (year)	23.77 ± 1.78	23.17 ± 1.79	24.13 ± 1.70	1.87
Body Weight (lb)	171.38 ± 30.37	149.33 ± 22.27	184.60 ± 26.87	4.68*

Note: Values are M ± SD, degrees of freedom for t-tests are 46.
*$p < .001$.

four test velocities were greater for the male group (n = 30) as opposed to the female group (n = 18). Calculations of independent t-tests comparing descriptive data of the male (n = 30) and female (n = 18) groups are presented in Table 1.

A wide variation of the descriptive measurements can be seen in Table 2. The lowest hamstring peak torque measurement for the female group was 7 ft/lb, while the lowest for the male group was 12 ft/lb, both at 180°/s. The lowest quadricep peak torque measurement occurred again at 180°/s. The female group low was 24 ft/lb while the male group low was 30 ft/lb. The highest peak torque measurements for females and males were found at 30°/s for both the quadriceps and hamstring. The female group's highest peak torque measurements were 173 ft/lb for the quadricep and 100 ft/lb for the hamstring. The male group high for the quadricep and hamstring were 264 and 162 ft/lb, respectively. A difference of only 1 ft/lb was found between the highest measurements of hamstring peak torque at 30 and 60°/s for the females (100 vs 99 ft/lb, respectively) and for the males 162 vs 161, respectively).

Correlation Coefficients of Descriptive Characteristics

Pearson product-moment correlations were calculated to determine relationships among the four velocities, age, and body weight of the entire group. Correlations were considered strong if $r \geq .70$ and moderate if $r \geq .30$ (Jaeger, 1990). Table 3 presents the correlation results for the variables of test prediction: quadricep and hamstring peak torque at 30, 60, 120, and 180°/s; age; body weight; and gender.

Table 2

Range of Total Group and Gender Comparison of the Subjects

Characteristics	Total Group	Females	Males
	N = 48	n = 18	n = 30
PT Quadricep 30°/s (ft/lb)	71 - 264	71 - 173	105 - 264
PT Hamstring 30°/s (ft/lb)	16 - 162	16 - 100	55 - 162
PT Quadricep 60°/s (ft/lb)	46 - 237	46 - 144	81 - 237
PT Hamstring 60°/s (ft/lb)	16 - 161	16 - 99	59 - 161
PT Quadricep 120°/s (ft/lb)	37 - 191	37 - 117	57 - 191
PT Hamstring 120°/s (ft/lb)	17 - 133	17 - 86	27 - 133
PT Quadricep 180°/s (ft/lb)	24 - 164	24 - 96	30 - 164
PT Hamstring 180°/s (ft/lb)	7 - 120	7 - 80	12 - 120
Age (year)	20 - 28	20 - 28	21 - 28
Body Weight (lb)	103 - 248	103 - 197	138 - 248

Note: Values are range of scores.

Table 3

Matrix of Correlation Coefficients of the Descriptive Characteristics of the Subjects

Variable	1	2	3	4	5	6	7	8	9	10
1. PT Quadricep 30°/s	1.00									
2. PT Hamstring 30°/s	.82*	1.00								
3. PT Quadricep 60°/s	.83*	.73*	1.00							
4. PT Hamstring 60°/s	.74*	.85*	.86*	1.00						
5. PT Quadricep 120°/s	.74*	.70*	.89*	.85*	1.00					
6. PT Hamstring 120°/s	.67*	.80*	.84*	.94*	.89*	1.00				
7. PT Quadricep 180°/s	.75*	.71*	.87*	.80*	.92*	.87*	1.00			
8. PT Hamstring 180°/s	.62*	.73*	.79*	.84*	.83*	.92*	.92*	1.00		
9. Age	.00	.21	.11	.20	.08	.16	.08	.14	1.00	
10. Body Weight	.53*	.58*	.58*	.65*	.60*	.58*	.49*	.45*	.27	1.00

*$p < .01$.

Strong relationships were found for correlations among quadricep peak torque measurements at 30, 60, 120, and 180°/s; hamstring peak torque measurements at 30, 60, 120, and 180°/s; and body weight. Testing order and age showed weak correlations with the other variables. Strong correlations of peak torque were observed for the hamstring between 120°/s and 60°/s ($\underline{r}$ = .94) and between 180°/s and 60°/s ($\underline{r}$ = .92). A strong correlation of quadricep peak torque was also observed between the 180°/s and 120°/s velocities ($\underline{r}$ = .92). A strong correlation was noted between quadricep and hamstring peak torque at 180°/s ($\underline{r}$ = .92).

Hamstring peak torque at 120°/s was also strongly correlated with hamstring peak torque at 60°/s ($\underline{r}$ = .84) and quadricep peak torque at 120°/s ($\underline{r}$ = .83). Peak torque of the quadricep at 60°/s strongly correlated with quadricep peak torque at 30°/s ($\underline{r}$ = .83) hamstring peak torque at 60°/s ($\underline{r}$ = .86), quadricep and hamstring peak torque at 120°/s ($\underline{r}$ = .89, $\underline{r}$ = .84, respectively), and quadricep peak torque at 180°/s ($\underline{r}$ = .87). The relationships found between quadricep and hamstring peak torque may have been affected by gravity since correction was not made during this study.

Strong correlations between quadricep peak torque at 30°/s and, as previously mentioned, at 60°/s ($\underline{r}$ = .83), and with hamstring peak torque at 30°/s ($\underline{r}$ = .82) were found. In addition, hamstring peak torque at 30°/s was also strongly correlated with hamstring peak torque at 60°/s ($\underline{r}$ = .85). Strong correlations were also revealed for both muscle groups at 30°/s and the other variables except for age which showed a weak correlation. Body weight was moderately correlated with hamstring peak torque at 60°/s ($\underline{r}$ = .65).

Analyses of Variance Related to Testing Order

A one-way analysis of variance (ANOVA) was conducted for both quadricep peak torque and hamstring peak torque to determine if significant differences ($p < .05$) were present between the peak torque measurements and the submaximal velocity testing order. The p value was reduced by the number of ANOVA tests resulting in $p > .008$ ($p = .05 / 6 = .008$) (Keppel, 1982). Six subgroups ($n = 8$) represented one of each of the six possible combinations of testing orders of 60, 120, and 180°/s. The six subgroups of test order were analyzed to determine the effect on peak torque measurements of the quadricep and hamstring.

The null hypothesis stated that there would be no significant difference between testing order and peak torque of the quadricep or hamstring. Failure to reject the null hypothesis resulted as the analyses of variance showed no significant ($p > .008$) differences for quadricep peak torque at 60°/s (F (5, 42) = .7222,), at 120°/s (F (5, 42) = .9759), or at 180°/s (F (5, 42) = .5317). No significant ($p > .008$) differences were seen for hamstring peak torque at 60°/s (F (5, 42) = 1.1219), at 120°/s (F (5, 42) = .7095), or at 180°/s (F (5, 42) = .6398).

Multiple Regression Analyses

Prediction of the criterion variable of peak torque at 30°/s from the predictor variables of peak torque at 60, 120, and 180°/s; age; body weight; and gender was examined through stepwise multiple regression analyses. Prediction equations for both quadricep peak torque (QuadPT) and hamstring peak torque (HamPT) were developed through forward regression analyses to present equations that could be utilized when peak torque measurements at 60, 120, and 180°/s were available. Multiple correlation coefficients (R), coefficients of determination ($\underline{R}^2$), and standard errors of estimate (SEE) were calculated from the regression analyses.

Table 4 presents the multiple regression equations for prediction of quadricep peak torque at 30°/s. Stepwise multiple regression analyses showed quadricep peak torque at 60°/s alone as the only significant ($\underline{p} < .05$) predictor variable of quadricep peak torque at 30°/s ($\underline{R} = .832$, $\underline{R}^2 = .692$, SEE = 23.544 ft/lb). However, the strongest correlation ($\underline{R} = .846$, $\underline{R}^2 = .715$, SEE = 24.000 ft/lb) was calculated in Equation 6 when all of the predictor variables had been included in the analyses. Quadricep peak torque at 60°/s accounted for 69.2% of the variance of quadricep peak torque at 30°/s. Equation 6 shows that all of the predictor variables combined accounted for 71.5% of the variance of quadricep peak torque at 30°/s.

The multiple regression equations for predicting hamstring peak torque at 30°/s are shown in Table 5. Hamstring peak torque at 60°/s, as seen in Equation 1, was shown as the only significant ($\underline{p} < .05$) predictor variable of hamstring peak torque at 30°/s ($\underline{R} = .852$, $\underline{R}^2 = .726$, SEE = 14.637 ft/lb). Alone, hamstring peak torque at 60°/s accounts for 69.2% of the variance. The strongest correlation and lowest standard error of estimate was found in Equation 5 ($\underline{R} = .856$, $\underline{R}^2 = .732$, SEE = 15.149 ft/lb) when age, hamstring peak torque at 180°/s, body weight, and hamstring peak torque at 120°/s were added to the basic equation. When gender was included in Equation 6, the correlation remained the same while the standard error of estimate rose slightly ($\underline{R} = .856$, $\underline{R}^2 = .733$, SEE = 15.315 ft/lb). The predictor variables in Equation 6 accounted for 73.3% of the variance of hamstring peak torque at 30°/s.

Table 4

Multiple Regression Equations for Predicting Quadricep Peak Torque at 30°/s from Peak Torque at 60, 120, and 180°/s

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Equation 1 ($\underline{R}$ = .832; $\underline{R}^2$ = .692; SEE = 23.544 ft/lb)
QuadPT 30°/s (ft/lb) = 26.752 + .892(QuadPT 60°/s)

Equation 2 ($\underline{R}$ = .837; $\underline{R}^2$ = .701; SEE = 23.450 ft/lb)
QuadPT 30°/s (ft/lb) = 79.078 + .903(QuadPT 60°/s) - 2.266(Age)

Equation 3 ($\underline{R}$ = .841; $\underline{R}^2$ = .707; SEE = 23.467 ft/lb)
QuadPT 30°/s (ft/lb) = 75.398 + .843(QuadPT 60°/s) - 2.765(Age) + .139(Body Weight)

Equation 4 ($\underline{R}$ = .842; $\underline{R}^2$ = .709; SEE = 23.658 ft/lb)
QuadPT 30°/s (ft/lb) = 76.054 + .755(QuadPT 60°/s) - 2.750(Age) + .142(Body Weight) + .116(QuadPT 180°/s)

Equation 5 ($\underline{R}$ = .845; $\underline{R}^2$ = .715; SEE = 23.720 ft/lb)
QuadPT 30°/s (ft/lb) = 80.409 + .817(QuadPT 60°/s) - 2.980(Age) + .189(Body Weight) + .290(QuadPT 180°/s) - .276(QuadPT 120°/s)

Equation 6 ($\underline{R}$ = .846; $\underline{R}^2$ = .715; SEE = 24.000 ft/lb)
QuadPT 30°/s (ft/lb) = 86.900 + .817(QuadPT 60°/s) - 3.057(Age) + .183(Body Weight) + .291(QuadPT 180°/s) - .289(QuadPT 120°/s) - 1.658(Gender)

Note. All peak torque measurements were measured in ft/lb; age was measured in year; body weight was measured in lb; gender was coded as male = 1 and female = 2.

Table 5

<u>Multiple Regression Equations for Predicting Hamstring Peak Torque at 30°/s from Peak Torque at 60, 120, and 180°/s</u>

Equation 1 ($\underline{R}$ = .852; $\underline{R}^2$ = .726; SEE = 14.637 ft/lb)
HamPT 30°/s (ft/lb) = 12.388 + .862(HamPT 60°/s)

Equation 2 ($\underline{R}$ = .853; $\underline{R}^2$ = .728; SEE = 14.752 ft/lb)
HamPT 30°/s (ft/lb) = -2.559 + .853(HamPT 60°/s) + .661(Age)

Equation 3 ($\underline{R}$ = .854; $\underline{R}^2$ = .729; SEE = 14.883 ft/lb)
HamPT 30°/s (ft/lb) = -3.048 + .797(HamPT 60°/s) + .695(Age) + .072(HamPT 180°/s)

Equation 4 ($\underline{R}$ = .855; $\underline{R}^2$ = .731; SEE = 15.014 ft/lb)
HamPT 30°/s (ft/lb) = -5.618 + .751(HamPT 60°/s) + .582(Age) + .088(HamPT 180°/s) + .048(Body Weight)

Equation 5 ($\underline{R}$ = .856; $\underline{R}^2$ = .732; SEE = 15.149 ft/lb)
HamPT 30°/s (ft/lb) = -5.357 + .835(HamPT 60°/s) + .548(Age) + .169(HamPT 180°/s) + .052(Body Weight) - .171(HamPT 120°/s)

Equation 6 ($\underline{R}$ = .856; $\underline{R}^2$ = .733; SEE = 15.315 ft/lb)
HamPT 30°/s (ft/lb) = 1.374 + .838(HamPT 60°/s) + 485(Age) + .177(HamPT 180°/s) + .043(Body Weight) - .195(HamPT 120°/s) - 1.900(Gender)

<u>Note</u>. All peak torque measurements were measured in ft/lb; age was measured in year; body weight was measured in lb; gender was coded as male = 1 and female = 2.

Summary

The purpose of this study was to determine the strongest combination of variables which will best predict maximal (30°/s) isokinetic knee strength through stepwise regression analyses. Of the data gathered from 48 male and female subjects, moderate to strong correlations for all test variables were found, with significant differences between genders. The experimental procedures used in this study provided adequate rest when measuring peak torque, which was seen with no significant differences in the results of the ANOVA for test order and peak torque. The ANOVA was not significant leading to a failure to reject the null hypothesis stating that no significant difference would exist between testing order and peak torque measurements. Results of this study showed peak torque at 30°/s was significantly predicted by peak torque at 60°/s for both the quadricep and hamstring, thus, the null hypothesis was rejected. The conclusion of this analysis states that of the predictor variables used, knee peak torque at 60°/s was the most significant predictor of knee peak torque at 30°/s for both the quadricep and hamstring muscle groups.

Chapter 5

DISCUSSION, CONCLUSIONS, & RECOMMENDATIONS

In chapter five the discussion, conclusions, and recommendations drawn from this study will be presented. The purpose of this study was to determine the strongest combination of variables which will best predict maximal (30°/s) isokinetic knee strength through stepwise regression analyses. Forty-eight male and female subjects performed isokinetic testing of the knee at 30, 60, 120, and 180°/s. Peak torque measurements from the latter three velocities, age, weight, and gender were used as predictor variables to predict peak torque at 30°/s. Conclusions are based on descriptions of central tendency scores, independent t-tests, Pearson product-moment correlations, and stepwise and forward multiple regression analyses of the data gathered during this study. The final portion of Chapter 5 provides recommendations for future research.

Discussion of Descriptive Characteristics

The standard deviation at all four test velocities was greater for the male group (n = 30) as opposed to the female group (n = 18). The larger number of subjects in the male group could explain this finding. However, with equal sized gender groups (n = 20), Gross, McGrain, et al. (1989) reported larger standard deviations for 20 to 40 year old males (30.01 ± 5.95 years) tested at 60 and 180°/s than for the 20 to 40 year old females (30.09 ± 5.80 years). In comparison to the 20 to 40 year old group in the Gross, McGrain, et al. study, the females had similar quadricep and hamstring peak torque means and standard deviations at 60°/s (106.06 ± 26.57 vs. 107.42 ± 23.41 ft/lb, 66.67 ± 18.63

vs. 68.24 ± 12.23 ft/lb, respectively), and at 180°/s (64.61 ± 19.70 vs. 66.00 ± 16.36 ft/lb, 47.78 ± 18.81 vs. 51.83 ± 12.55 ft/lb, respectively).

Mean peak torque for both males and females decreased as the isokinetic velocity was increased, which can be explained by the principle of the Force-Velocity Curve (Kovi, 1992; Perrin, 1993). This principle states that as the generation of velocity is increased, there will be a proportional decrease in the generation of force. Isokinetic exercise measurements in human subjects has shown that torque capabilities decline as angular velocity increases (Jorgensen, 1976). This study demonstrated similar findings of greater muscular force generated at lower velocities than at higher velocities.

The variation seen in peak torque measurements at each velocity is possibly related to the muscle fiber type composition of each subject. The recruitment of the muscle fibers is dependent on the resistance placed on the muscle rather than the speed of the movement. The fiber type composition of the subject is an important factor in determining the potential isokinetic force a subject can exert at all velocities. Individuals with more fast twitch fibers will potentially be able to exert greater force at faster velocities than those with less fast twitch fibers (Perrin, 1993). At lower velocities, both slow and fast twitch muscle fibers are recruited due to the maximal effort exerted, and at higher velocities the reliance on the slow twitch fibers is decreased (Perrin, 1993; Suter, Herzog, Sokolosky, Wiley, and Macintosh, 1993). The investigator made a concerted effort to treat each subject equally. Keeping in mind each subject had a different motivational level, the results may differ when replicated. All subjects appeared to give maximal efforts throughout the testing session.

Discussion of Correlation Coefficients

In calculating coefficients of determination, the relationship explained between quadricep peak torque at 30°/s and peak torque at 60, 120, and 180°/s was found to be 68.9%, 54.8%, and 56.3%, respectively. For hamstring peak torque at 30°/s and peak torque at 60, 120, and 180°/s, the explained variance was 54.8%, 44.9%, and 38.4%, respectively. The multiple regression analyses would be affected since similar correlations may not improve the value of prediction, but will be discussed later in this chapter.

Moderate to strong correlations were found among all variables ($r = .45$ to $r = .94$) except for age ($r = .00$ to $r = .21$). Body weight correlated moderately with peak torque at all velocities and was greatest with hamstring peak torque at 60°/s where 42.3% of the variance was explained. Baron (1995) reported significant correlations ($p < .05$) for subjects age 20 to 29 years between body weight and extension torque measurements. Similar correlations ($p < .05$) between body weight ant peak torque were found by Borges (1989) in a study of subjects age 20 to 70 years. However, Natri, Järvinen, Latvala, and Kannus (1996) reported no correlation between body weight and isokinetic performance. The contradiction indicates a need for more definitive research of the relationship, if any, between body weight and isokinetic strength.

Discussion of Analyses of Variance

The null hypothesis stated that there would be no significant difference between testing order and peak torque of the quadricep or hamstring. Failure to reject the null hypothesis resulted as the analyses of variance showed no significant ($p > .008$) differences for quadricep peak torque at 60°/s (F (5, 42) = .7222,), at 120°/s (F (5, 42) = .9759), or at 180°/s (F (5, 42) = .5317). No significant

($p > .008$) differences were seen for hamstring peak torque at 60°/s (F (5, 42) = 1.1219), at 120°/s (F (5, 42) = .7095), or at 180°/s (F (5, 42) = .6398).

No significant differences were found between testing order and peak torque of the quadricep or hamstring. Therefore, testing order in accordance with the protocol for this study does not affect the peak torque measurement of the quadricep and hamstring. The ample amount of rest time in between test velocities could explain why there were no effects from test order. The rest time was utilized after a pilot study in which subjects did not report experiencing fatigue during testing or muscle soreness after testing.

Discussion of Multiple Regression Analyses

Six equations for predicting peak torque at 30°/s of the quadricep and hamstring muscle groups were developed following this investigation. The stepwise multiple regression analyses revealed that peak torque at 60°/s was the only significant ($p < .05$) predictor of peak torque at 30°/s for both the quadricep and hamstring. The primary null hypothesis stating that there would not be a significant predictor of peak torque at 30°/s was rejected. It does not appear that the predictor variables used in this study other than peak torque at 60°/s have any real effect on the prediction of peak torque at 30°/s as the increases in statistics are rather small. In fact, if examining coefficients of multiple determination and standard error of estimate as whole numbers, no change is seen from one equation to the next.

When examining the correlations of the regression equations developed through forward regression analysis for the quadricep, the increase is not significant enough to reveal any variables other than peak torque at 60°/s as significant predictor variables. Quadricep peak torque at 60°/s explains 69.2% of the variance, while the other variables combined to account for 2.3% of the variance of peak torque at 30°/s. The variables relate strongly to the criterion variable, which in turn does not improve the value of the prediction. This means other factors not utilized in this study may improve the prediction value of the quadricep equations. The variables used do, however, have practical significance in that they relate to each other and do not reduce the multiple correlation coefficient value. The standard error of estimate increased only 0.456 ft/lb, which relates to the strong correlations of the variables. However, the change in error is minor while error overall is large (SEE = 24.00 ft/lb). This could be the result of investigator error during calculation of peak torque measurements. Measurements were calculated by the investigator using a Cybex II Chart Data Card (Appendix A) in which 1/16 inch marks represented 6 ft/lb (180 ft/lb setting) and 12 ft/lb (360 ft/lb setting) per mark (Cybex Manual, 1983).

In comparison to the equations used in the study by Gross, McGrain, et al. (1989), in which anthropometric data was used to predict peak torque at 60 and 180°/s, the inclusion of the predictor variables was different from the present study. Although in this study, keeping in mind the variables of age, body weight, and gender were combined with peak torque variables, age and body weight were the second and third variables, respectively, added into the quadricep equations. Gender was also added into the equation, but added the least amount to the prediction value. Gross, McGrain, et al. reported weight and gender added into their equations for 60°/s as the third and fifth variables, respectively. For their equation at 180°/s, weight and gender were added in third and fourth, respectively. After comparing these two studies, gender appears to possibly have more value in the equation for quadricep peak torque when other strength variables are not included in the equation.

Six equations were developed to predict hamstring peak torque at 30°/s from the predictor variables of peak torque at 60, 120, and 180°/s, age, body weight, and gender. Stepwise multiple regression analysis showed 72.6% of the variance accounted for by hamstring peak torque at 60°/s. After the inclusion of all variables, forward multiple regression analyses revealed only 0.7% more of the variance had been accounted for. Again, the similar correlations between the predictor variables and the criterion variable explains why the variance accounted for was not improved. Standard error of estimate only increased by 0.678 ft/lb after all predictor variables had been included in the equation. In the hamstring equations, the coefficients of Equation 5 and 6 were the same ($R = .856$); and with the inclusion of gender in Equation 6, SEE decreased 0.166 ft/lb. This indicated that gender did not play a strong role in predicting hamstring strength.

Gross, McGrain, et al. (1989) entered gender as the second variable and weight as the last variable in their hamstring equations for predicting both 60 and 180°/s. This suggests that when other peak torque values are utilized, gender does not play a role in the prediction as strongly as when only anthropometric data is used. This was also seen when comparing mean peak torque values of the quadriceps by gender. The mean was lower for females, indicating that if peak torque values are not included, gender lowers the predicted peak torque value for females. Inclusion of peak torque values at various velocities in the equation may replace the need for gender in the Gross, McGrain, et al. study.

The level of activity of the subjects could explain the differences seen in this investigation and the Gross, McGrain, et al. (1989) investigation. Some of the female subjects had higher peak torque measurements than some of the male subjects. The crossover seen in peak torque measurements between genders could indicate that activity level may play a greater role in the relationship to peak torque than does gender. In addition to activity level, body size may have affected the peak torque measurements. Variables such as leg length and height could possibly explain some of the remaining variance in the equations (Leiber, 1992). Controlling for activity level and/or body size in future studies may yield better prediction.

Interestingly, when comparing the six equations of the quadricep analyses to those of the hamstring analyses, peak torque at 180°/s and body weight were reversed. For the quadricep equations, body weight came before peak torque at 180°/s. When looking at the Pearson product-moment correlations (Table 2) for body weight, the correlation was slightly stronger between quadricep peak torque at 180°/s and body weight (r = .49) than for hamstring peak torque at 180°/s and body weight (r = .45). However, these results were not significant enough to draw conclusions from. Body weight appeared a stronger predictor variable for quadricep peak torque than for hamstring peak torque in the Gross, McGrain, et al. (1989) study. Of the non-strength related variables used in both studies, body weight seems to have the strongest relationship with strength. This phenomenon may be explained by the concept that a muscle's maximal contractile force is proportional to its cross sectional area. Thus, the larger the subject, the greater the potential to elicit a greater muscular force (Astrand & Rodahl, 1986).

Summary

The purpose of this study was to determine the strongest combination of variables which would best predict maximal (30°/s) isokinetic knee strength through stepwise regression analyses. A pilot study was carried out to verify adequate rest periods between velocities. Male ($n = 30$) and female ($n = 18$) subjects aged 23.77 ± 1.78 years underwent isokinetic testing to determine quadricep and hamstring peak torque at 30, 60, 120, and 180°/s. Demographic data of age, body weight, and gender were also included as predictor variables. Strong correlations ($p > .01$) ranging from $r = .62$ to $r = .85$ were found between quadricep and hamstring peak torque at 30°/s and hamstring peak torque at 60, 120, and 180°/s. One-way analyses of variance determined no significant ($p > .008$) difference existed between peak torque measurements and testing order. Stepwise multiple regression analyses revealed peak torque at 60°/s of the quadricep as the strongest predictor of quadricep peak torque at 30°/s ($R = .832$, $R^2 = .692$, $SEE = 23.544$). Likewise, hamstring peak torque at 60°/s best predicted hamstring peak torque at 30°/s ($R = .852$, $R^2 = .726$, $SEE = 14.637$). Significant improvements in prediction were not seen with the addition of the remaining predictor variables.

Conclusions

Within the limits of this study, the following conclusions were drawn.

1. The predictor variable of quadricep peak torque at 60°/s accounted for 69.2% of the variance of quadricep peak torque at 30°/s.
2. Hamstring peak torque at 60°/s provided the greatest prediction of maximal strength by accounting for 72.6% of the variance of hamstring peak torque at 30°/s.

3. Protocol used in this study for testing order did not effect peak torque measurements of the quadricep or hamstring.

Recommendations

The following recommendations are made based on the realization that this study could have been conducted differently. In the hope that future research will further explore the problem at hand, it is recommended that:

1. When conducting isokinetic testing, subjects should undergo a separate session to experiment and familiarize themselves to isokinetic movement while not effecting fatigue during the test period.
2. Additional data, such as height and/or leg length, be added to the prediction equations to attempt to increase the explained variance.
3. Closer analysis of the relationship between body weight and isokinetic peak torque may provide interesting information into the prediction of peak torque through anthropometric data.
4. A reliable means of gravity correction should be completed during testing to allow for the use of the equations in varying altitudes.
5. This study be replicated using adolescents or geriatric subjects who are not capable of eliciting the same muscle measurements as the subjects in this study which may improve the generalizability of the results.
6. A larger sample size would improve statistical power in turn allowing for greater experimental inference.
7. A similar study be carried out using a different joint, such as the shoulder.
8. The study be replicated while controlling for activity levels to provide results explaining if activity level of the subjects has an effect on the prediction value.

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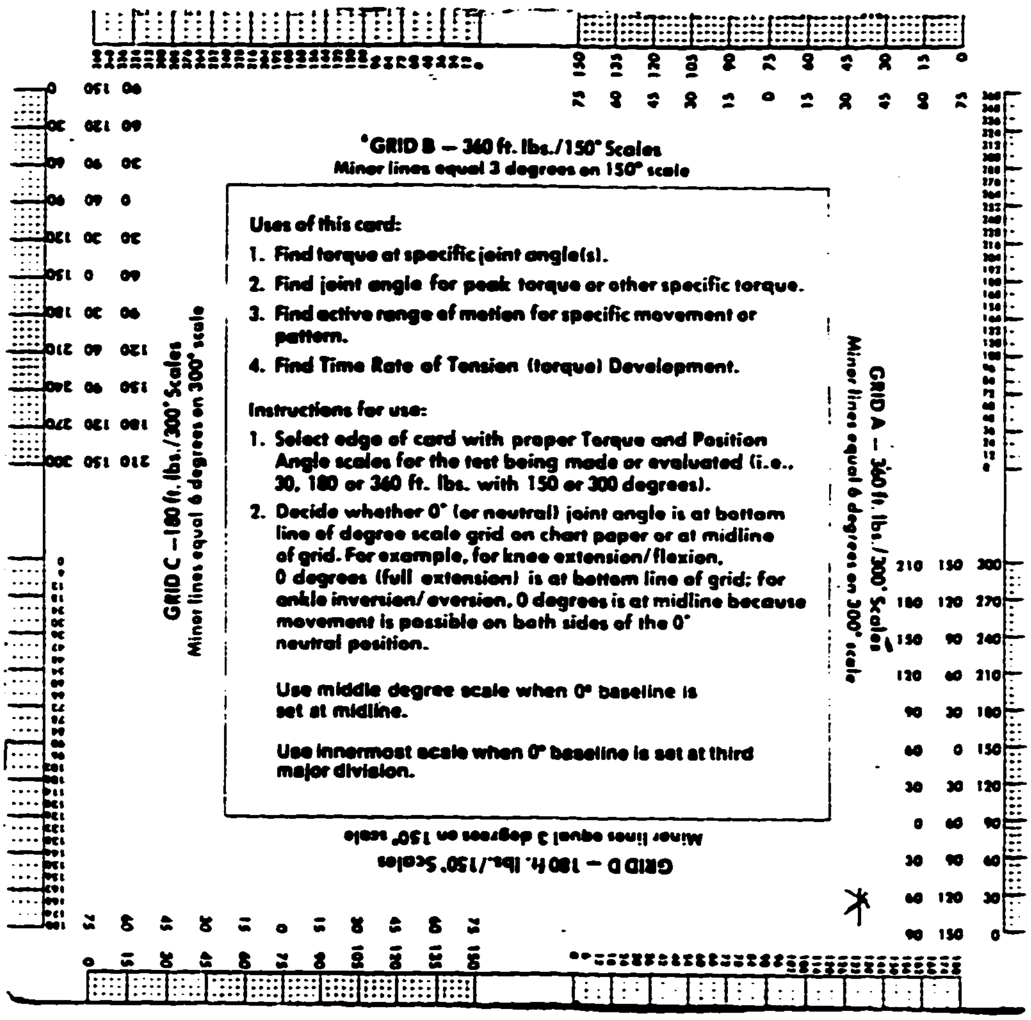
APPENDIX A

CYBEX II CHART DATA CARD

Appendix A

Cybex II Chart Data Card



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Victor Verhage
Director of Education and Research, Sales and Marketing of CA and NV
One Verano
Foothill Ranch, CA 92610
(714) 461-0694.

APPENDIX B

AGREEMENT TO PARTICIPATE IN RESEARCH

SJSU SAN JOSE STATE UNIVERSITY

A campus of The California State University

College of Applied Sciences and Arts • *Department of Human Performance*
One Washington Square • San José, California 95192-0054 • 408/924-3010 • FAX 408/924-3053

Agreement to Participate in Research

Responsible Investigator: Amanda J. Sinclair, ATC, Graduate Student

Title of Study: The Prediction of Maximal Isokinetic Knee Strength from Submaximal Isokinetic Knee tests.

I,____________________________________,volunteer to participate in a research study using submaximal isokinetic knee strength to predict maximal knee strength. I understand that testing will be performed during one session at San Jose State University and that I am to wear shorts to the session. Prior to testing, I will be asked to complete a demographic questionnaire and health questionnaire. My weight will be assessed on a platform scale. I will then perform quadricep and hamstring stretches. A four minute stationary bicycle ride will serve as the warm-up for testing.

Isokinetic testing will be done on a Cybex II+ dynamometer. Test velocities will be 30°/s, 60°/s, 120°/s, and 180°/s. I understand that my thigh, lower leg, and torso will be strapped snugly to the Cybex seat. I will be read written instructions about the isokinetic testing. First, I will perform a set of repetitions at maximal velocity followed by a five minute rest. I will perform three submaximal repetitions, five maximal repetitions, and two submaximal repetitions at each testing velocity. I will then perform repetitions at submaximal velocities and will receive a three minute rest between velocities. I understand that all testing will be performed by a certified athletic trainer (ATC) experienced in isokinetic testing.

I understand that joint and/or muscular discomfort or injury, such as a muscle strain, can occur during testing. Strain to my cardiopulmonary system may also occur. Potential benefits from my participation may be a) knowledge of the strength level of my dominant knee and b) general knowledge and understanding of isokinetic testing. No alternative procedure is available for this study, and no compensation will be received.

Initials: ____________

I am aware that the results from this study may be published but my confidentiality will not be compromised. Materials relating myself to my identification number will be kept in a locked file cabinet and will be destroyed immediately after the study is completed.

Any questions, comments, or concerns may be directed to the Responsible Investigator at (408) 978-5917. Complaints regarding this study can be presented to Dr. James Bryant, Human Performance Department Chair, at (408) 924-3010. Questions or complaints about the research, subjects' rights, or research-related injury may be presented to Serena Stanford, Ph.D., Associate Academic Vice President for Graduate Studies and Research, at (408) 924-2480.

I understand that should I choose to participate in this study, I may withdraw from the study, or any part thereof, at any point without penalty. My consent is given voluntarily and by signing and dating below, I indicate that I have read and received a copy of this consent form.

______________________________ ______________

Subject's Signature Date

____

Subject's Printed Name

______________________________ ______________

Investigator's Signature Date

APPENDIX C

HEALTH HISTORY QUESTIONNAIRE

Appendix C

Health History Questionnaire

Please answer the following questions honestly to the best of your ability. All information will be kept strictly confidential. Please use only your identification number, do not write your name on this form.

Identification Number: ________________

A. **Joint-Muscle Status** Please place an "X" in the areas in which you currently have problems.

Joint Areas	Muscle Areas
( ) Wrists	( ) Arms
( ) Elbows	( ) Shoulders
( ) Shoulders	( ) Chest
( ) Upper Spine and Neck	( ) Upper Back and Neck
( ) Lower Spine	( ) Abdominal Regions
( ) Hips	( ) Lower Back
( ) Knees	( ) Buttocks
( ) Ankles	( ) Thighs
( ) Feet	( ) Lower Leg
( ) Other ______________ ______________	( ) Feet
	( ) Other ______________ ______________

B. **Health Status** Please place an "X" if you previously or currently have any of the following conditions.

( ) High Blood Pressure	( ) Anemia
( ) Heart Disease or Dysfunction	( ) Hernias
( ) Peripheral Circulatory Disorder	( ) Thyroid Dysfunction
( ) Lung Disease or Dysfunction	( ) Pancreas Dysfunction
( ) Arthritis or Gout	( ) Liver Dysfunction
( ) Edema	( ) Kidney Dysfunction
( ) Epilepsy	( ) Neural Dysfunction
( ) High Blood Cholesterol or Triglyceride Levels	( ) Acute Infection
	( ) Multiple Sclerosis
( ) Diabetes or Blood Sugar Abnormality	
( ) Others that you feel the investigator should know about:	

____

Identification Number: ________________

C. **Physical Perceptions** Please indicate any unusual sensations or perceptions. Place an "X" if you have recently experienced or currently experience any of the following during rest or physically active periods.

Rest	Physically Active
( ) Chest Pain	( ) Chest Pain
( ) Heart Palpitations	( ) Heart Palpitations
( ) Unusually Rapid Breathing	( ) Unusually Rapid Breathing
( ) Overheating	( ) Overheating
( ) Muscle Cramping	( ) Muscle Cramping
( ) Joint Pain	( ) Joint Pain
( ) Nausea	( ) Nausea
( ) Light Headedness	( ) Light Headedness
( ) Loss of Balance	( ) Loss of Balance
( ) Loss of Condition	( ) Loss of Condition
( ) Extreme Weakness	( ) Extreme Weakness
( ) Numbness	( ) Numbness
( ) Mental Confusion	( ) Mental Confusion
( ) Other ________________	( ) Other ________________

D. **Test Specific** Please indicate with an "X" if you have experienced any of the following to the lower extremities during the previous two months.

Relative	Absolute
( ) Pain	( ) Poor Soft Tissue Healing
( ) Limited Range of Motion	( ) Severe Pain
( ) Effusion or Synovitis	( ) Extreme Limited Range of Motion
( ) Chronic 3rd Degree Sprain	( ) Severe Effusion
( ) Subacute Strain	( ) Unstable Joint or Bone
	( ) Acute Strain
	( ) Acute Sprain

Yes( ) No( ) Have you ever undergone surgery on your lower extremity?
If yes, what for? ____
when? ____

APPENDIX D

DEMOGRAPHIC QUESTIONNAIRE

Appendix D

Demographic Questionnaire

Please answer the following information as accurately as you can. All information will be kept strictly confidential. The number at the bottom of this page will be your identification number for all other questionnaires and data sheets. PLEASE PRINT

Date: ___________

Name: ____

Age: ___________________________ Sex: ______________________________

Mailing Address: ____

Local Phone: ____

Work Phone: ____

Height: _________________________ Weight: __________________________

Physician Name: ____

Physician Phone: ____

Whom to Contact in Case of Emergency: ______________________________

Relationship: ___________________ Phone: ___________________________

Identification Number: ___________________

APPENDIX E

SCRIPT FOR ISOKINETIC KNEE TESTING

Appendix E

Written Script for Isokinetic Knee Testing

(Instructions will immediately follow the warm-up on the stationary bicycle.)

You will now undergo isokinetic strength testing of your dominant leg. These tests will determine your strength at four velocities. Please sit in the seat which would place your dominant leg in the center of the Cybex. Your knees should be bent to 90°. The seat back will be adjusted by the investigator to ensure that your back rests firmly against it. Next, the investigator will fasten a strap around your thigh, one around your torso, and another just above your ankle. The straps should be as tight as possible, but your comfort should not be compromised. During testing, please grasp the sides of your seat.

You will perform three submaximal repetitions at each velocity so that your positioning can be checked and also to familiarize yourself with isokinetic movement. You will then be given a 3-minute rest period. During a repetition think "push then pull." After the initial maximal set of repetitions, you will have a 5-minute rest period. After each set of submaximal repetitions, you will have a 3-minute rest period, at which time the investigator will adjust the Cybex II+ for the next set of repetitions. For the test repetitions, you will perform three submaximal repetitions, five maximal effort repetitions, and two submaximal finishing repetitions in a continuous manner. The investigator will notify you when you are on the third repetition with the statement "maximal effort," indicating that the next five repetitions are to be completed at your maximal effort. The investigator will also notify you of your eighth repetition with the statement "last maximal," indicating that you may perform the next two repetitions at a submaximal level. Once all four testing velocities have been accomplished, the straps will be removed and testing is completed. If at any point in the testing session you feel pain, stop the movement and notify the investigator. Do you have any questions?

APPENDIX F

VARIABLE REPORT FORM

Appendix F

Variable Report Form

Identification Number: ____________

Age: ______________

Weight: ______________

Gender: F M

Peak Torque: (quad/ham)

	rep. 4	5	6	7	8
30°/s	___/___	___/___	___/___	___/___	___/___
60°/s	___/___	___/___	___/___	___/___	___/___
120°/s	___/___	___/___	___/___	___/___	___/___
180°/s	___/___	___/___	___/___	___/___	___/___

Testing Order: ___________________________

SJSU SAN JOSE STATE UNIVERSITY

A campus of The California State University

Office of the Academic Vice President • Associate Academic Vice President • Graduate Studies and Research
One Washington Square • San José, California 95192-0025 • 408/924-2480

TO: Amanda J. Sinclair
1623 Ixias Ct.
San Jose, CA 95124

FROM: Serena W. Stanford *Serena W. Stanford*
AAVP, Graduate Studies & Research

DATE: January 7, 1997

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Prediction of Maximal Isokinetic Knee Strength from Submaximal Isokinetic Measurements"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Serena Stanford, Ph.D., immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.