Concentric and Eccentric Isokinetic Normative Ratio Values of the Quadriceps Muscle in Asymptomatic Knee Subjects

Donna Ho
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CONCENTRIC AND ECCENTRIC ISOKINETIC

NORMATIVE RATIO VALUES OF THE QUADRICEPS MUSCLE

IN ASYMPTOMATIC KNEE SUBJECTS

by

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An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1996
This Independent Study, submitted by Donna Ho in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title
Concentric and Eccentric Isokinetic Normative Ratio Values of the Quadriceps Muscle in Asymptomatic Knee Subjects

Department
Physical Therapy

Degree
Masters of Physical Therapy

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Signature

Date 12/7/95

Dorita Ho

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ACKNOWLEDGMENTS

With the completion of this research project, I would like to express my sincere appreciation and gratitude to so many people who have contributed in so many ways, perhaps without realizing how much they have influenced or taught me along the way. First of all, to Mark Romanick, MPT, ATC, for providing patience and guidance with this project from its early stages of being just an idea to its critical final stages of development. To all of my friends and fellow 1996 PT graduates for giving their time and support, particularly Deane Chinen, my "Kin-Com pal", for making those grueling practice/test sessions and sack dinners bearable. To my buddies for life - Lena Kam, Jody Yoshishige, Angela Lo, and Colleen Tanaka.

Finally, a special thanks to the most deserving and influential people in my life. Your believing in me and unending encouragement, support, and love have been a continuous source of strength. To Denise Yamashiro, for enduring the journey with me, regardless of my stressed moods, a scout's honor. And to my older brothers - Craig, for guiding me with advice and looking out for me the way that only an older brother can; Alan, for uncovering the artful side within me and showing me how to view the world through different eyes; and Bo, for fueling the fire of my competitiveness, for you will always have my admiration and will always be an inspiration.
To my Dad and Mom,
who helped make my dreams a reality
and for truly being the wind beneath my wings...
ABSTRACT

Technological advances in isokinetic devices allow the clinician to objectively assess and rehabilitate injuries using concentric and eccentric contractions at different speeds. The purpose of this research project is to establish concentric and eccentric normative ratio values of the quadriceps muscle on the Kinetic Communicator (Kin-Com, Chattecx Corp., Chattanooga, TN) dynamometer. A sample of 19 females and 12 males aged 20-38 (mean for females $= 24.32 \pm 3.87$, mean for males $= 27.67 \pm 5.80$) were tested on the Kin-Com for maximum concentric and eccentric torque values during knee extension using a $70^\circ$ range of motion at 90 and $120^\circ$/sec. The actual test included three sets of three repetitions of voluntary maximum isokinetic contractions of the quadriceps at each speed. The mean maximal eccentric/concentric ratio (ft-lbs) was $1.32 \pm 0.31$ for the females and $1.30 \pm 0.18$ for the males at $90^\circ$/sec. At $120^\circ$/sec, the ratio was $1.34 \pm 0.33$ for the females and $1.34 \pm 0.30$ for the males. These values can be used clinically as an indicator of progress or for formulating accurate rehabilitation goals for patients with knee involvement.
CHAPTER I
LITERATURE REVIEW

One important concern in rehabilitation programs, besides range of motion and functional return to activities, is muscle strength recovery. The recovery of muscular strength after an injury or surgery is crucial for the patient returning to normal activity\(^1\) or athletic participation\(^2\). For this reason, research has been aimed at determining strength values for healthy individuals so that a baseline criteria for rehabilitation programs would exist. This will allow objective measurement of strength recovery from injury or surgery.\(^1,3\)

Rehabilitation programs often incorporate isokinetic exercises on a dynamometer to increase muscular strength. Isokinetic exercise is a type of resistive exercise with adjustable constant angular velocity and accommodated resistance at the specified velocity.\(^4,5,6\) In simpler terms, it controls the speed of muscular performance.\(^7\) An isokinetic device provides a mechanical means of maintaining a constant rate of limb movement speed regardless of the magnitude of forces generated by the muscles. Increased muscular output produces increased resistance.\(^7,8\) Therefore, the resistance developed by the dynamometer is in proportion to the amount of muscle force exerted.\(^8\) This allows the muscle to exert a maximum contraction throughout its full range of motion without permitting acceleration to occur.\(^7,9\) Throughout the range of motion, the resistance generated by the dynamometer accommodates to the amount of muscle force exerted.\(^7\) The resistance is lessened at the point in the range when the muscle has the least mechanical advantage. Likewise, the
resistance is increased at the point in the range when the muscle has the greatest mechanical advantage.

Isokinetic exercise involves concentric and eccentric contractions. A concentric contraction involves approximation of the muscle's origin and insertion. Conversely, an eccentric contraction involves separation of the muscle's origin and insertion. The eccentric function of muscles occurs particularly in the deceleration of extremities, in the lowering of body weight to sit down or descend stairs, and in providing stability. Eccentric contractions, as well as concentric contractions, are important components of normal gait and in most functional movements included in both daily living and sports. When measured on an isokinetic device, muscles generate higher forces with an eccentric contraction as opposed to a concentric contraction at a given speed. With increasing speeds the eccentric contraction force has shown to plateau or increase, while the concentric contraction force has shown to decrease. In 1967, Hislop and Perrine presented the principles of isokinetic exercise. Since then, studies have shown isokinetic exercises to be more effective in muscle force production than isometric or isotonic exercises. Thistle et al performed a clinical study comparing muscle strengthening by means of isokinetic exercise versus isometric exercise and progressive resistance exercise. Results indicated that the group utilizing isokinetic exercise scored higher in quadriceps maximal force exerted than the two groups participating in the other types of exercise. Moffroid et al designed a similar study and results showed isokinetic exercise to be a more rapid means of increasing muscular work than either isometric or isotonic exercise.
In addition to being more effective in muscle force production when compared to isometric or isotonic exercises, isokinetic exercises have features of objectivity\textsuperscript{22,23} and reproducibility of tests.\textsuperscript{16,18,24-27} Physical therapists employ the isokinetic dynamometer as a resistive exercise device for rehabilitation programs and for an objective measure of muscle strength determination and strength progression.\textsuperscript{6} An example of the use of a dynamometer's objective measure can be seen in Shelbourne and Nitz's\textsuperscript{28} accelerated rehabilitation protocol after an anterior cruciate ligament (ACL) reconstruction. One criteria for permitting a return to light sports activity as early as the eighth week post ACL reconstruction is strength of the injured knee exceeding 70% of the noninjured knee when measured on a dynamometer.

Various isokinetic dynamometers include the Biodex B-2000 (Biodex Corporation, Shirley, NY), Cybex II (Cybex, Division of Lumex, Inc., Ronkonkoma, NY, 11779), Kinetic Communicator (Kin-Com, Chattecx Corp., Chattanooga, TN), and the Lido 2.0 (Davis, CA). Data from these different dynamometers may not be comparable.\textsuperscript{29} Therefore, values recorded from one dynamometer should not be compared to those obtained from other dynamometers. If data is compared, however, caution should be used.\textsuperscript{4}

Isokinetic measurements include the parameter options of peak torque, joint angle at which peak torque occurred, average torque, total work, average work, total power and average power.\textsuperscript{6} Torque measured on an isokinetic dynamometer is the product of the muscle force recorded at the resistance pad times its perpendicular distance from the axis of rotation to the pad.\textsuperscript{8,22,26,29} Peak torque is the highest torque generated at one point in the range of motion.\textsuperscript{7,12,16} Average torque reflects the mean torque produced throughout the range of motion.\textsuperscript{12,16} Work is the product of muscular force exerted through a range of
motion. Power is the work output of muscles at a specific speed of contraction.

Technological advances in isokinetic devices allow the clinician to objectively assess and rehabilitate injuries. Several studies have examined the performance of the quadriceps femoris muscle using isokinetic devices. Data on peak torque values and/or mean peak torque values of the quadriceps in noninjured subjects include those measured by the Biodex B-2000, Cybex-exerciser and Cybex II, Kin-Com, and the Lido 2.0.

Dynamometers also have the ability to measure muscle balance. For example, the strength ratio between the quadriceps and hamstrings can be assessed. In healthy individuals, the generally accepted hamstring/quadriceps torque ratio has been reported to be 50-77%. However, studies have shown that muscular strength baseline values should be age and sport specific. The bilateral quadriceps/hamstrings ratio has also been assessed. The comparisons of muscular balance within an extremity and muscular balance between bilateral extremities have been used to investigate the possible contribution for deficiencies in strength that may make athletes more prone to injury. It appears plausible that muscle imbalances around the knee may predispose the occurrence of knee pathologies and that a corrective program may help prevent injuries. Cahill and Griffith conducted a study in which preseason muscle conditioning for high school football players decreased the rate of knee injuries.

However, Grace et al found no significant relationship between preseason strength imbalances and subsequent knee joint injuries in high school football players. Strength imbalances were designated by a difference of 10% or more between right and left extremities or between
hamstring/quadriceps ratios within the same extremity. Therefore, the data did not support the notion that an isokinetic muscle imbalance predisposes a joint to injury, or that a program to correct the weakness will prevent injury.

Muscle balance can also be assessed by comparing the eccentric/concentric torque ratio of a specific muscle. The Kin-Com dynamometer is capable of producing concentric and/or eccentric contractions. Before the Kin-Com was introduced, isokinetic exercise and testing were limited to concentric contractions. A study by Bennett and Stauber22 included a sample of subjects with anterior knee pain. Isokinetic tests showed that the subject's uninvolved knees had eccentric torque values that were equal to or greater than the concentric values. However, the knees with anterior pain had angle-specific eccentric torque deficits of 15% or more than the concentric values during the 35-60° range. The subjects participated in a concentric and eccentric training program at 30, 60, and 90°/sec on the Kin-Com three times per week. Pain relief was reported and torque deficiency was corrected (eccentric values were equal to or greater than concentric values) in most of the 41 subjects after 2-4 weeks of participating in the exercise program. Only 27 subjects were included in the post tests. The other subjects dropped out of the program once their pain was alleviated. The researchers found that the subjects with anterior knee pain produced lower angle-specific eccentric torques than concentric torques.

In response to Bennett's and Stauber's22 study suggesting that a deficit of an angle-specific eccentric/concentric torque pattern might be used as a predictor of knee pain, Trudelle-Jackson et al.36 performed a study to estimate the percentage of asymptomatic subjects who demonstrated a quadriceps eccentric/concentric torque deficit. The results found by Trudelle-Jackson et al.36
contradicted the results found by Bennett and Stauber.\textsuperscript{22} The results by Trudelle-Jackson et al\textsuperscript{36} indicated that, in general, asymptomatic subjects did not demonstrate a deficit. However, when analyzing individual subject's torques, 35-54\% of the subjects did demonstrate an eccentric/concentric torque ratio deficit of 0.85 or below, as defined by Bennett and Stauber.\textsuperscript{22} This deficit ratio was demonstrated at some point in the range of motion between 24 and 64\(^\circ\). When the average eccentric/concentric torque deficit was compared over the entire range of motion, 11-31\% demonstrated the ratio deficit. Females exhibited a significantly greater average eccentric/concentric torque deficit than males. This study indicated that a substantial percentage of asymptomatic subjects demonstrated the 85\% eccentric/concentric torque deficit suggested by Bennett and Stauber.\textsuperscript{22} However both studies did differ in terms of speed and range of motion used. Further research for eccentric/concentric torque ratio values are needed to settle the controversy between the opposing results of these studies. A study by Shirakura et al\textsuperscript{10} showed that an eccentric/concentric ratio imbalance was not the cause of ACL injuries as ACL injured knees were not significantly different from the controls. These studies are important because they suggest that muscular imbalances are not necessarily the cause of knee pain or ACL injuries.

Mean concentric and eccentric peak torque values of the quadriceps muscle measured on the Kin-Com for both females and males have been reported in the literature.\textsuperscript{1,10-12,15,18,29,33} Although not the intent of the researchers, the data gathered in these studies can be calculated to express a ratio between the eccentric and concentric contractions. Thus, the calculated female eccentric/concentric torque ratio values include 1.11 at 50\(^\circ\)/sec,\textsuperscript{1} 1.09 at 60\(^\circ\)/sec,\textsuperscript{11} 1.46 at 180\(^\circ\)/sec,\textsuperscript{33} and 1.68 at 180\(^\circ\)/sec.\textsuperscript{11} Vandervoort et al\textsuperscript{12}
compared the eccentric/concentric ratio between elderly (aged 66-89) and young (aged 20-29) females and found the elderly ratios to be higher than the young ratios at two different speeds. The ratio was 1.31 (elderly) and 1.10 (young) at 45°/sec and 1.64 (elderly) and 1.16 (young) at 90°/sec. Male eccentric/concentric torque ratio values include 1.04 at 50°/sec, 1.05 at 60°/sec, and 1.42 at 180°/sec. Hanten and Ramberg reported male ratios of 1.27 at 30°/sec, 1.37 at 60°/sec, 1.52 at 90°/sec, 1.57 at 120°/sec, 1.77 at 150°/sec, 1.94 at 180°/sec, and 1.97 at 200°/sec. Tredinnick and Duncan found male ratios of 1.09 at 60°/sec, 1.30 at 120°/sec, and 1.47 at 180°/sec.

Only two studies actually reported a torque ratio measured on the KinCom although this was not the intent of the studies either. Alexander reported a 30°/sec concentric/eccentric ratio of .94 and .95 for elite female and male sprinters, respectively. At 230°/sec, the ratio was .67 for the females and .77 for the males. To remain consistent with the other calculated values, the calculated eccentric/concentric ratio was 1.07 (females) and 1.04 (males) at 30°/sec and 1.47 (females) and 1.30 (males) at 230°/sec. Shirakura et al provided a control group eccentric/concentric ratio of 1.53 (females) and 1.30 (males) when tested at 60°/sec.

There is a lack of documented eccentric/concentric isokinetic torque ratios of the quadriceps femoris muscle in the current literature. Therefore, it is the purpose of this present study to provide eccentric/concentric normative ratio values of the quadriceps femoris muscle for the Kin-Com dynamometer for the normal population. These values can be used as a basis of comparison for patients with knee involvement. Such guidelines can assist clinicians in defining strength deficits, indicating strength progress, and formulating accurate rehabilitation goals for patients with knee involvement.
CHAPTER II
METHODS

Subjects
Healthy female (n = 19) and male (n = 12) college physical therapy students representing varied physical activity patterns from light recreational exertion to intensive recreational exertion were recruited as volunteers from the University of North Dakota. Guidelines (see Appendix) for this study were established by the Institutional Review Board at the University of North Dakota. Subjects without prior history of knee surgery, knee pathology, knee pain or a condition which would limit range of motion in their dominant lower extremity participated in this study. The female ages ranged from 20-36 years, with a mean of 24.32 years (SD = 3.87). The male ages ranged from 22-38 years, with a mean of 27.67 years (SD = 5.79). All subjects were fully informed of the procedures and signed a statement of informed consent (see Appendix) prior to participation in this research project.

Instrumentation

Preliminary Health Screening
A preliminary screening (see Appendix) was performed to identify any history of knee involvement such as surgery, pathology, pain, or condition which would limit range of motion. Any person with such knee involvement was eliminated from this study.
Kinetic Communicator Dynamometer

The Kin-Com (model 125AP with software version 4.06) dynamometer was used in this study. This computer-controlled, hydraulically driven isokinetic dynamometer is capable of measuring concentric and eccentric contractions. A lever arm allows the attached limb to move through a specified range of motion. The lever arm at its starting position first moves freely and remains unresisted until its speed reaches the predetermined operator selected speed. Once this occurs, the dynamometer accommodates to give maximal resistance throughout the entire range of motion. Acceleration of the lever arm past the set operating speed is mechanically prevented by the device.

The Kin-Com has features which make it an easy, adaptable apparatus to utilize in the clinic. Its versatility allows the lever arm to be positioned in a variety of ways for exercises or the evaluation of different body joints. For patients with limited range of motion, the lever arm can be adjusted within the patient's range limit while still offering maximal resistance within that range. The Kin-Com employs a Screentouch monitor system which allows the patient to engage in visual feedback. This can be used as a motivational tool by encouraging better performance in an effort to exceed previous repetitions or scores.

The reliability of the Kin-Com must be determined before any quantitative measures of muscular evaluation and its interpretation can be utilized. Otherwise, any difference during repeated testing cannot be distinguished between measurement error and actual changes in muscle performance. The Kin-Com has been proven to be a reliable isokinetic dynamometer by previous
studies when testing the quadriceps muscles of healthy subjects during concentric and eccentric actions.\textsuperscript{1,11,18,24,25,27}

Kramer\textsuperscript{16} found that a continuous concentric-eccentric cycle protocol can produce highly reliable isokinetic torques of the knee extensors and flexors. Farrell and Richards,\textsuperscript{24} in testing the reliability and validity of the Kin-Com, found that force measurements averaged a difference of 3.2\% or less of the actual applied load. The results of a study by Kues et al\textsuperscript{25} suggest that two days of practice are needed to obtain reliable measurements of knee extensor torque. A study conducted by Wilhite et al\textsuperscript{27} focused on determining speed testing order and its effect on the reliability of concentric and eccentric measurements of the quadriceps. Results indicated that subjects should be tested at slower speeds before higher speeds. Tredinnick and Duncan\textsuperscript{18} found high reliability for measures of peak torque at 120 and 180\textdegree/sec but relatively low reliability at 60\textdegree/sec.

\textbf{Procedure}

The knee is the largest joint in the body, as well as the most complex.\textsuperscript{31} It is subjected to more stress than any other joint during walking, running, and sport activities.\textsuperscript{2,30} The quadriceps femoris muscle serves as the primary knee extensor and as the active stabilizer of the knee joint. Thus, the quadriceps femoris is important for knee function and prevention of injuries.\textsuperscript{30} The strength of these muscles are significantly correlated to knee function. The knee was selected to be researched in this study because it is a joint that requires frequent evaluation and strengthening. This is because it has one of the highest incidence of injury in sports.\textsuperscript{32}

The strength (torque) generated by the quadriceps femoris muscles during concentric and eccentric contractions of the dominant lower extremity
was measured on a Kin-Com dynamometer. The practice sessions were programmed in the sequential mode and the test session in the protocol mode. The continuous option of the isokinetic protocol was selected. The acceleration and deceleration phases of the lever arm were set on high, which maximized the amount of time the subject's limb moved at constant velocity. To initiate movement of the lever arm, a minimum force of 1 lb was required against the resistance pad.

Each subject participated in two practice sessions and one test session on the Kin-Com dynamometer. The sessions were scheduled so that the practice and test sessions were separated by at least one day. This allowed for adequate muscle recovery so maximal performance could be achieved during the test, since eccentric contractions have shown to produce delayed onset of muscle soreness. Practice sessions, however, could be performed on consecutive days. Each subject was asked to refrain from any resistive lower extremity exercise during the approximate four day span of the practice and test sessions to prevent skewing of the results. The same examiner conducted the practice and test sessions in order to exclude interexaminer variability.

Each subject reported to the Physical Therapy Department at the University of North Dakota (Room 253 Medical Science North Unit) and completed a preliminary health screening form in order to eliminate any individual with a history of knee involvement (surgery, pathology, pain, or condition which would limit range of motion). During the first practice session, the subject's age, gender, and self-selected physical activity level were recorded and the subject's dominant lower extremity was determined. Dominance was determined by the lower extremity the subject chose for hopping when asked to perform single-leg hopping.
At the beginning of each practice and test session each subject participated in a standard warm-up, which consisted of a five minute ride on a stationary bike ergometer at a pace described as moderate intensity. Then five static stretches with ten second holds each of the quadriceps and hamstring muscles of the dominant extremity were performed. Following the warm-up, the subject began the practice or test procedure of the dominant leg on the KinCom.

The subject was seated on the Kin-Com seat bench with the back supported at a position which produced a hip angle of approximately 80° of flexion (see Figure 1). Trunk, hip, and test leg stabilizing devices were used to limit any excessive or substitution movements from the subject. Two seat belt straps stabilized the trunk and hip, while an adjustable pad firmly pressed against the distal portion of the thigh stabilized the test leg. With the knee flexed at 90°, the axis of rotation of the dynamometer lever arm was aligned with the lateral epicondyle of the femur, or the approximate knee axis position. The resistance pad was placed just above the malleoli and secured with a velcro strap that encircled the leg. A towel was placed between the subject's shin and the resistance pad for comfort. Using the scale on the lever arm, the distance of the resistance pad to the axis of rotation was recorded so that the same position could be obtained with subsequent sessions. The distance was also used to convert the force to torque. To reduce influence of the upper body, the subject was not allowed to grasp the bench during testing.

Within the Kin-Com's exercise program, the knee was selected for the joint setting and extension was selected for the movement pattern. The lever arm was horizontally positioned and identified as the anatomical reference of 0° with positive direction set toward the floor. The range of motion was set from
Figure 1. Position for Knee Extensions on the Kin-Com Dynamometer.
15° to 85°, for a total range of motion of 70°. This range was chosen to prevent the leg from being forced into full extension or too much flexion. The minimum force against the resistance pad required to activate and to maintain movement of the dynamometer arm was set at 1 lb. The dynamometer would not function below this 1 lb force. This minimal force, a safety feature of the Kin-Com, ensures that the lever arm movement will stop should the subject cease to push against the resistance pad due to pain or discomfort. The speed at which the subject practiced and tested was 90°/sec and 120°/sec.

Verbal descriptions of concentric and eccentric quadriceps muscle actions in relation to the test were standardized and always given by the same examiner. Instructions were given to straighten the knee with as much effort as possible (for the concentric action), then to maximally resist the knee being bent (for the eccentric action). The concentric phase consisted of the subject pushing against the resistance pad or extending the knee from 85° to 15° of flexion. The eccentric phase consisted of the subject resisting the resistance pad as it returned from 15° to 85° of flexion to the start position. The knee extensions, always beginning with the concentric muscle action, included continuous concentric-eccentric quadriceps contractions with no pause between the muscle actions or between the cycles.

Two practice sessions were designed to precede the test session in order to familiarize the subjects with the Kin-Com's operation, to gain proficiency in the performance of reciprocal concentric and eccentric quadriceps contractions, and to control the effects of learning. The practice procedure consisted of: (1) a warm-up set of ten submaximal repetitions at 90°/sec, (2) three sets of five repetitions performed at 50%, 75%, and 100% of maximal effort contractions at 90°/sec, and (3) three sets of five repetitions
performed at 50%, 75%, and 100% of maximal effort contractions at 120°/sec. There was a one minute rest between each set to minimize fatigue. After the practice procedure was complete, the subject was allowed additional practice sets if the subject and the examiner believed that the subject's performance was not to the best of their ability using both muscle actions.

The Kin-Com was calibrated at the beginning of each test session day before any testing began, according to the manufacturer's protocol described in the Kin-Com's Operator's Manual. The test procedure consisted of: (1) a warm-up set of three submaximal repetitions at 90°/sec, (2) three sets of three repetitions of maximal effort contractions at 90°/sec, and (3) three sets of three repetitions of maximal effort contractions at 120°/sec. There was a one minute rest between each set to minimize fatigue. Instructions of maximal contractions of the quadriceps muscle in the full range of motion were encouraged. To ensure maximal effort by the subject, verbal encouragement was provided during both the practice and test sessions. The subject was allowed to view the computer screen for visual feedback on performance during the practice sessions only.

Data Analysis

The peak torque values of the quadriceps femoris muscle was measured both concentrically and eccentrically. The power/work program in the report section of the Kin-Com isokinetic program was used to identify the peak torque value for each test. The highest peak torque values, one for the concentric contractions and another for the eccentric contractions, attained during the 90°/sec test session were recorded to calculate the eccentric/concentric ratio value for each subject. The same was done for the 120°/sec test session. The eccentric/concentric ratio was calculated by dividing the maximal eccentric peak
torque value by the maximal concentric peak torque value. Descriptive statistical techniques were used to describe the ratio values from the sample and provided guidelines for the normative ratio values for the general public. The group average and standard deviation were determined for the eccentric/concentric ratios measured at each speed. Male and female subjects were separated into two groups to mitigate gender influence.
CHAPTER III
RESULTS

Maximal peak torque values (ft-lbs) for the concentric and eccentric contractions of each subject were determined as the highest torque produced from the nine repetitions at each speed. The eccentric/concentric ratio was calculated by dividing the maximal eccentric peak torque value by the maximal concentric peak torque value. The eccentric/concentric ratio values of the quadriceps muscle at 90°/sec were 1.32 ± 0.31 for the females and 1.30 ± 0.18 for the males (see Table 1). At 120°/sec, the ratio values were 1.34 ± 0.33 for the females and 1.34 ± 0.30 for the males. The mean eccentric and concentric peak torque values at each of the test speeds are also presented in Table 1.

During the concentric contraction, 32% (6 out of 19) of the female subjects recorded peak torque values that were greater at the slower velocity. During the eccentric contraction, 47% (9 out of 19) of the female subjects recorded peak torque values that were greater at the faster velocity. The peak torque values were greater during the eccentric contraction in 16 female subjects at 90°/sec and in 17 female subjects at 120°/sec.

During the concentric contraction, 58% (7 out of 12) of the male subjects recorded peak torque values that were greater at the slower velocity. During the eccentric contraction, 33% (4 out of 12) of the male subjects recorded peak torque values that were greater at the faster velocity. The peak torque values were greater during the eccentric contraction in all of the male subjects at 90°/sec and in 10 male subjects at 120°/sec.
<table>
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<th>Speed (deg/sec)</th>
<th>Mean Eccentric (ft-lbs)</th>
<th>Mean Concentric (ft-lbs)</th>
<th>Eccentric/Concentric Ratio</th>
<th>Standard Deviation</th>
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CHAPTER IV
DISCUSSION

It is difficult to make meaningful comparisons between the findings of this study and those reported in the literature. This is because any discrepancies may be due to differences in the designs of the studies, such as sample characteristics (age, gender, subject groupings, or varying activity levels) or test methods (subject position setup, subject stabilization setup, muscles tested, exercise mode tested, velocities tested at, or testing apparatus used).\textsuperscript{26,30,31}

Therefore, comparisons between studies should be made with caution. Results from this study relate specifically to the Kin-Com and should not be compared to eccentric/concentric torque ratio values generated on other dynamometers.\textsuperscript{1}

Studies using similarities of sample characteristics (healthy females and males) and test characteristics (quadriceps femoris muscle tested concentrically and eccentrically for peak torque values at the same speed on the Kin-Com) were compared with this study. The data in regards to the sample characteristic of gender was separated because of the physiological and structural differences between females and males.\textsuperscript{4} There is also a general difference between females and males in strength-speed type performance.\textsuperscript{1}

For the females tested at 90\(^o\)/sec, results from this study of the mean eccentric/concentric ratio of 1.32 ± 0.31 fell between calculated ratios of 1.16\textsuperscript{12} and 1.64.\textsuperscript{12} At 120\(^o\)/sec, there were no female calculated ratios in the literature tested under the similar characteristics mentioned above in which results from this study could be compared. For the males tested at 90\(^o\)/sec, results from this
study of \(1.30 \pm 0.18\) were lower than the calculated ratio of 1.52.\textsuperscript{15} At 120°/sec, a result of \(1.34 \pm 0.30\) was closer to a calculated ratio of 1.30\textsuperscript{18} rather than 1.57.\textsuperscript{15}

The relationship between velocity and contraction type has been demonstrated by other studies.\textsuperscript{19} Peak torque has been shown to be greater at the slower velocity during concentric contractions,\textsuperscript{4,5,9,11,14,16-19,21} while equal or greater at the faster velocity during eccentric contractions.\textsuperscript{11,12,15-18,20}

When individual peak torque values were compared, it was found that less than half of the females and males in this study followed the general trend observed in other studies of decreasing concentric peak torque values and increasing eccentric peak torque values with increasing speeds. The one exception was the male concentric peak torque values.

During the concentric contraction, 32\% (6 out of 19) of the female subjects recorded peak torque values that were greater at the slower velocity. During the eccentric contraction, 47\% (9 out of 19) of the female subjects recorded peak torque values that were greater at the faster velocity. During the concentric contraction, 58\% (7 out of 12) of the male subjects recorded peak torque values that were greater at the slower velocity. During the eccentric contraction, 33\% (4 out of 12) of the male subjects recorded peak torque values that were greater at the faster velocity.

The results of this study did correlate better with the trend that muscles will generate higher forces with an eccentric contraction as opposed to a concentric contraction at a given speed.\textsuperscript{1,4,12,14-19} The peak torque values were greater during the eccentric contraction in 84\% (16 out of 19) of the female subjects at 90°/sec and in 89\% (17 out of 19) of the female subjects at 120°/sec. The peak torque values were greater during the eccentric contraction in 100\%
of the male subjects at 90°/sec and in 83% (10 out of 12) of the male subjects at 120°/sec.

Previous studies concentrating on concentric and eccentric contraction differences have found that eccentric exercise has (1) greater mechanical efficiency,17,38 (2) a metabolic energy cost that is less,17,37,38 and (3) greater loading of the elastic components of the muscle.17 These reasons may be why eccentric contractions demonstrate greater torque productions than concentric contractions at a given speed.33

There was a wide range in the peak torque values produced among the individual subjects. This discrepancy could be attributed to the subject sample which represented varied physical activity patterns from light recreational exertion to intensive recreational exertion. Or it could rely on the fact that each repetition in this study required continuous concentric-eccentric quadriceps contractions with no pause between the muscle actions, which required a certain level of coordination. Measures to account for this allowed additional practice sets if the subject and the examiner believed that the subject's performance was not to the best of their ability using both muscle actions. However, none of the subjects required additional practice.

There is no clear pattern in the peak torques produced and it is believed that there are many contributing factors. Possible internal variables include subject motivation, skill level, and fatigue. Possible external variables include practice and test instructions, stabilization, and axial alignment. Steps were taken in an attempt to minimize the external variables. The instructions were standardized and always given by the same examiner. Although stabilization and axial alignment procedures were replicated with each session, the exact positioning of the subject and the machine is not precise.
The results from this study for quadriceps eccentric/concentric ratios can be clinically applied in that the data from the healthy population can be used toward goals of rehabilitation programs for individuals recovering from knee injury or surgery. However, it must be remembered that this study was conducted on a small number of female and male subjects. Since the sample size was small, caution is advised when generalizing the results of this study to the general population.

Recommendations for further research include expanding the scope of this study to other age groups, larger sample sizes, and comparable test protocols. Standardized and comparable test protocols are factors to consider when maximizing the comparability of data.
CHAPTER V

CONCLUSIONS

The present study measured eccentric and concentric peak torque values with the Kin-Com isokinetic dynamometer for females and males without any history of health-related conditions of the knee. The mean eccentric and concentric peak torque values for females at 90°/sec are 155.96 ft-lb and 120.79 ft-lb, respectively. At 120°/sec, the mean eccentric and concentric peak torque values are 162.78 ft-lb and 125.92 ft-lb, respectively. The mean eccentric and concentric peak torque values for males at 90°/sec are 257.81 ft-lb and 198.38 ft-lb, respectively. At 120°/sec, the mean eccentric and concentric peak torque values are 244.24 ft-lb and 187.10 ft-lb, respectively.

This study was proposed to establish normative eccentric/concentric data of the knee extensors. Based on the outcome of this study, it is suggested that females have an approximate ratio of quadriceps eccentric strength to concentric strength of $1.32 \pm 0.31$ at 90°/sec and $1.34 \pm 0.33$ at 120°/sec, while males demonstrated $1.30 \pm 0.18$ at 90°/sec and $1.34 \pm 0.30$ at 120°/sec. These values are provided as a basis of comparison to assist clinicians in defining strength deficits, indicating strength progress, and formulating accurate rehabilitation goals for patients with knee involvement.
Technological advances in isokinetic devices allow the clinician to objectively assess and rehabilitate injuries using concentric and eccentric contractions at different speeds. The purpose of this research project is to establish concentric and eccentric normative ratio values of the quadriceps muscle on the Kinetic Communicator (Kin-Com, Chattanooga Corp., Chattanooga, TN) dynamometer. The subject will straighten the knee against resistance during the concentric muscle action and will resist the knee being bent during the eccentric muscle action. Forty to fifty subjects with no knee pain and no known knee pathology in their dominant lower extremity will be recruited as volunteers to participate in this research project. There will be two practice sessions and one test session on the Kin-Com, with a standard warm-up preceding each session. The knee extensions will be performed at maximal voluntary effort through both eccentric and concentric phases in the 15°-85° range of motion at 90°/sec and 120°/sec. The concentric and eccentric peak torque values measured from this sample during the test session will be used to establish the normative ratio values for the general population.
PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

SUBJECTS:

It is anticipated that 40 to 50 male and female subjects from the University of North Dakota will be recruited as volunteers. It is anticipated that the ages of the subjects will range from 20 years to 30 years. These subjects must have no knee pain and no known knee pathology in their dominant lower extremity. The subjects will be fully informed of all procedures and will sign a statement of informed consent prior to participation in this research project.

METHOD:

Each subject will participate in two practice sessions to familiarize him/herself with the dynamometer's operation and in one test session on the Kin-Com dynamometer. The sessions will be scheduled so that the practice and test sessions will be separated by at least one day, but the practice sessions may be performed on consecutive days. All subjects will be asked to refrain from any resistive lower extremity exercise during the approximate four day span of the practice and test sessions, so as to not affect the results of this research project.

The subject will be screened to rule out any individual with a history of knee pain or pathology. During the first practice session, the subject's age and gender will be recorded and the subject's dominant lower extremity will be determined. The subject will be asked to hop on one leg and the lower extremity the subject chooses to hop on will be considered the dominant one. At the beginning of each practice and test session, all subjects will participate in a standard warm-up. First, the subject will ride for five minutes on a cycle ergometer at a pace described as moderate intensity. Second, the subject will perform five 10-second static stretches of the quadriceps and hamstring muscles of the dominant extremity. Following the warm-up, the subject will begin the practice or test procedures of the dominant leg on the Kin-Com.

The subject will be seated on the Kin-Com table with the back supported, producing a hip angle of about 80°. Trunk and test leg stabilizing devices will be used to limit any excessive or substitution movements from the subject. The axis of rotation of the dynamometer lever arm will be aligned with the lateral epicondyle of the femur. The resistance pad will be placed just above the malleoli and secured with a velcro strap. To reduce any influence of the upper body, the subject will not be allowed to grasp the bench during testing.

The range of motion will be set to 15°-85° for a total of 70°. The minimum force required to activate and to maintain movement of the dynamometer arm will be 1 lb, a force below which the dynamometer will not function, a safety feature of the Kin-Com. The speed at which the subject will be practicing and testing at will be 90°/sec and 120°/sec.
The practice procedure will consist of a warm-up set of ten repetitions at 90°/sec, followed by three sets of five repetitions performed at 50%, 75%, and 100% of maximal effort knee extensions. The knee extensions, always beginning with the concentric muscle action, will include continuous concentric-eccentric quadriceps contractions with no pause between the muscle actions or between the cycles. There will be a one minute rest between each set. After the three sets of five repetitions, the subject will be allowed more practice sets if the subject and investigator believe that the subject's performance was not to the best of their ability using both muscle actions. The subject will then repeat the procedure at 120°/sec.

The test procedure will consist of the same parameters as the practice procedure with the exception of three sets of three repetitions of maximal effort knee extensions being performed. There will be an one minute rest between each set and an one minute rest will separate the 90°/sec and 120°/sec test speeds. To better ensure maximal effort by the subject, verbal encouragement will be provided during both the practice and test sessions and the subject will be allowed to view the computer screen for visual feedback on performance during the practice sessions only.

The concentric and eccentric peak torque values measured at 90°/sec and 120°/sec during the test session will be used to establish the normative ratio values for each subject. Descriptive statistical techniques will be used to describe the ratio values from the sample and provide guidelines for the normative ratio values for the general public. The group average and standard deviation will be determined for the concentric and eccentric peak torque values measured at 90°/sec and 120°/sec. Male and female subjects will be separated into two groups.
3. BENEFITS: (Describe the benefits to the individual or society.)

This research project will seek to establish on the Kin-Com dynamometer concentric and eccentric normative ratio values of the quadriceps muscle in subjects who have no knee pain and no known knee pathology. These normative values can objectively be used as a standard reference in clinical measurements as to whether or not a patient is presenting with a deficient concentric and eccentric ratio. It can serve as a guideline to clinicians when assessing the rehabilitative concentric and eccentric ratio values of a patient with a knee injury and can be used as a treatment goal when establishing a specific treatment plan.

4. RISKS: (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psycho-logical, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

The risks of injury or discomfort to the subjects in this research project are minimal. Steps taken to minimize the risks of injury include a relatively slow practice and test speed on the Kin-Com and a minimum force of 1 lb will be required to activate and maintain movement of the dynamometer lever arm. Therefore, any force below that will deactivate the lever arm. The subject will also be given an emergency stop button which can be used to deactivate the lever arm at any time during the practice and test sessions. Any post-exercise discomfort that may result from the knee extensions performed on the Kin-Com may include some muscle fatigue and delayed onset of muscle soreness, both of which are treatment phenomena. The risk of sustaining a muscle strain is present as maximal effort performance is requested; however the warm-up procedure previously described will lessen the likelihood of that occurring. The experimental protocol used is similar to those used in physical therapy clinics when testing with isokinetic devices.
5. CONSENT FORM: A copy of the CONSENT FORM to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no CONSENT FORM is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept and for what period of time.

The consent forms will be kept in the University of North Dakota Physical Therapy Department's confidential file for two years after the completion of the research project. Forms will then be shredded and disposed. A copy of the consent form is attached.

6. For FULL IRB REVIEW forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development
University of North Dakota
Box 8138, University Station
Grand Forks, North Dakota 58202

On campus, mail to: Office of Research & Program Development, Box 134, or drop it off at Room 101 Twamley Hall.

For EXEMPT or EXPEDITED REVIEW forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

Principal Investigator

DATE: __________________

Project Director or Student Adviser

DATE: __________________

Training or Center Grant Director

DATE: __________________

(Revised 8/1992)
INFORMATION AND CONSENT FORM

TITLE: Concentric and Eccentric Normative Ratio Values of the Quadriceps Muscle in Asymptomatic Knee Subjects

You are being invited to participate in a research project conducted by Donna Ho, a student in Physical Therapy at the University of North Dakota. The purpose of this research project is to establish concentric and eccentric normative ratio values of the quadriceps muscle in normal knees on the Kinetic Communicator (Kin-Com, Chattecx Corp., Chattanooga, TN) dynamometer. For the purpose of this research project, a normal knee is defined as one having no knee pain and no known knee pathology.

You will be asked to perform two practice sessions and one testing session of knee extensions on the Kin-Com, with a standard warm-up preceding each session. The knee extensions will be performed at maximal voluntary effort through both eccentric and concentric phases. The practice sessions will be used to familiarize you with the Kin-Com and the muscle actions involved for the test session.

The sessions will be scheduled so that the practice and test sessions will be separated by at least one day, but the practice sessions may be performed on consecutive days. You will be asked to refrain from any resistive lower extremity exercise during the approximate four day span of the practice and test sessions, so as to not affect the results of this research project.

Each session will take approximately thirty minutes. You will be asked to report to the Physical Therapy Department at the University of North Dakota (Room 253 Medical Science North Unit) at an assigned time. You will then be asked to change into gym shorts for the experiment and your age and gender will be recorded.

Although the process of physical performance testing always involves some degree of risk, the risk of injury or discomfort under the test parameters in this research project is minimal and steps have been taken to minimize these risks. However, some muscle fatigue and delayed onset of muscle soreness as well as muscle strain may occur from participating in this research project.
Your name will not be used in any reports of the results of this research project. Any information that is obtained in connection with this study and that can be identified with you will remain confidential. The data will be identified by a number known only by the investigator. All written material from the research project will be kept in a locked file cabinet in the Physical Therapy Department at the University of North Dakota. All subject material will be destroyed upon completion of data analysis. Participation is entirely voluntary and your decision of whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigator involved is available to answer any questions you have concerning this research project, the procedures, and any risks or benefits that may arise from participating in the research project. In addition, you are encouraged to ask any questions concerning this research project that you may have in the future. Questions may be asked by calling Donna Ho at (701)777-5828. A copy of this consent form is available to all participants in the study.

In the event that this research activity results in a physical injury, medical treatment will be available, including first aid, emergency treatment, and follow up care as it is to a member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payer, if any.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS RESEARCH PROJECT IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this research project explained to me by ____________________________

__________________________________________  ____________________________
Participant’s Signature                      Date

__________________________________________  ____________________________
Witness                                      Date
Medical History Form

Client's name: ____________________________

I. Past Injuries
Do you have or have you had any of the following conditions? If so, please state when and the care you received if any.

- Concussion(s)
- Skull fracture(s)
- Neck injuries
- Shoulder injuries
- Elbow injuries
- Arm/wrist/hand injuries
- Rib cage injuries
- Back injuries
- Hip injuries
- Thigh injuries
- Knee injuries
- Lower leg injuries
- Ankle injuries
- Muscle strains/pulls
- Any injury to any body part not mentioned

Have you been advised to restrict activity during the past five years? If yes, please state reason.

________________________________________________________________________________________

II. Past Illnesses or Medical Problems
Do you now have, or have ever had any of the following conditions? If so, please state when and what kind of care you received.

Surgical operations:

Confinement to the hospital:

- Frequent headaches
- Fainting spells, dizziness, weakness
- Weakness or illness when exposed to high temperatures
- Epilepsy or convulsions
- Numbness or tingling
- Nosebleeds
- Difficulty breathing
- Frequent colds
- Pneumonia
- Tuberculosis
- Rheumatic fever
- Scarlet fever
- Heart murmur
Have you ever had an electrocardiogram? If yes, please state when and by whom.

- High blood pressure
- Arthritis
- Diabetes
- Any abnormal bleeding tendencies
- Anemia
- Thyroid disorders
- Skin disorders
- Allergies to food and medications
- Asthma
- Skin disorders

Loss of, or serious impairment of a paired organ (i.e. kidney, eye, lung). If yes, please state organ and time of incident.

- Hepatitis or jaundice
- Infectious mononucleosis (mono)
- Bowel cramps or upsets
- Frequent indigestion or heartburn
- Stomach ulcer
- Kidney and bladder problems
- Menstrual problems

III. Current Health History
Do you smoke? No  Yes packs/day
How long have you been smoking?
Are you taking any prescription medications? If so, what are they?

IV. Exercise Routine
Check the one which you feel describes your level of exercise over the past year:
- Intensive occupational and recreational exertion
- Moderate occupational and recreational exertion
- Sedentary work and intense recreational exertion
- Sedentary work and light recreational exertion
- Sedentary work and no recreational exertion

V. Present Illness
Are you presently having any pain, limitation of motion, or musculoskeletal problems? If so, please describe the problem.
Where is it located?
How long have you had the problem?
What makes it better?
What makes it worse?
Are you currently under treatment for the problem? If yes, please state the treatment.
Does this condition limit your physical activity? If yes, please explain how.
October 23, 1995

Ms. Anjanette Wong
3216 Collins Street
Honolulu, Hawaii 96815

Dear Anjanette,

I am requesting permission to include a copy of the enclosed photograph in my independent study project. Please sign below to authorize use of this photograph and return this letter in the enclosed envelope. Thank you for your assistance.

Sincerely,

Donna Ho

Donna Ho

I, Anjanette Wong, hereby authorize Donna Ho the use of the enclosed photograph in her independent study project.

Signature ____________________________ Date 10/30/95
REFERENCES


