The Relationship between Vertical Jump Scores and Peak Force Measurements of an Isokinetic Leg Press

David M. Silkey
University of North Dakota

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THE RELATIONSHIP BETWEEN VERTICAL JUMP SCORES AND PEAK FORCE MEASUREMENTS OF AN ISOKINETIC LEG PRESS

by

David Silkey
Bachelor of Science in Physical Therapy
University of North Dakota, 1995

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 David Silkey 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.

[Signatures]

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
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Department Physical Therapy

Degree Master of Physical Therapy

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Date 4/26/96

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ACKNOWLEDGMENTS

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ABSTRACT

This study evaluated potential correlations between related closed kinematic chain strength measurements on a Kin-Com isokinetic machine and a functional strength test. The correlation between standing vertical jump height and isokinetic leg press measurements were statistically analyzed. The following measurements were obtained from 22 subjects (mean age of 24.4 years): a body weight measurement, a vertical jump score, and the force measurements of an isokinetic leg press at 90°/second on each leg. Pearson correlation coefficients were significant (p < .001) when power quotient scores (vertical jump height multiplied by body weight) were compared to leg press results. However, second-order partial correlation coefficients did not find a significance (p > .005) between vertical jump scores and isokinetic leg press results when weight and gender were considered. A significant difference (p < .001) existed between left leg press and right leg press measures. Although isokinetics are useful for lower extremity assessment, this study found that the isokinetic leg press may not be appropriate in determining functional ability.
CHAPTER I
INTRODUCTION

Leg power is a major determinant of ability on many athletic playing fields and is an important aspect of daily function. It pertains to daily ambulation and locomotion along with the ability to engage competitively with an athletic opponent. Evaluation of leg power has become a comprehensive topic in rehabilitation and sports clinics. Clinical assessment of lower extremity strength includes a vast array of procedures and techniques, all of which determine the ability of an injured or healthy individual to participate in his/her respective activity. For this reason, lower extremity evaluative and treatment techniques have been developed in order to provide the optimum parameters. The majority of clinical lower extremity assessment is comprised of two techniques, isokinetic testing and functional testing.

An isokinetic dynamometer is a mechanical instrument that accommodates to resistance and controls velocity at a constant rate, while allowing movement throughout a specified range of motion.\(^1\text{–}^3\) The machine is preset at a constant velocity and as a subject increases or decreases muscle force, the machine will increase or decrease resistance in a directionally proportional manner.\(^1\text{–}^4\) Variable resistance allows for optimum muscle force
throughout the range of motion.\textsuperscript{5} This concept has been defined as “accommodating resistance.” Isokinetic testing is common in the clinic as it allows quantitative assessment of right/left limb comparison, torque/force production, range of motion measurement rate, rate of tension development, and angular comparison.\textsuperscript{1,2,4,6} Besides the clinical value of the aforementioned objective measures for documentation and assessment, therapists choose isokinetic machines because of patient safety\textsuperscript{7} and the reproducibility of results.\textsuperscript{8-10} The Kin-Com (Kinetic Communicator) dynamometer is one type of isokinetic machine.

Functional testing involves the assessment of individuals in a sport- or activity-specific manner. It allows clinicians to establish relationships between clinical evaluation and function.\textsuperscript{11} Literature shows that functional tests can include, but are not limited to, agility tests, running tests, hopping tests, and jumping tests.\textsuperscript{5,6,11-13}

Both forms of testing have benefits in the clinical setting, but within different aspects. Isokinetic testing gives a high reproducibility of results and clearly presents objective data. On the other hand, functional testing allows true activity-related assessment. The recent concentration on functional outcomes has led to questions about the correlation of isokinetic testing to functional activities.\textsuperscript{5,14,15}
CHAPTER II

LITERATURE REVIEW

The principles of kinematic chains in analyzing human motion and the effects of injury on this motion are useful in clinics. A kinematic chain refers to human movements that are interconnected and occur in a series of links. These links, or joints, are joined by a series of fixed segments upon which movement is created. Kinematics can be portrayed in two separate manners, open kinematic chain (OKC) and closed kinematic chain (CKC) (see Fig. 1). Both OKC and CKC are popular forms of assessment and treatment in the clinical setting.

Open kinematic chain movement occurs when the distal segment of a limb is free in space, meaning that movements of one segment will not cause movements at adjacent segments. Because the distal segment terminates in space, the isolation of a specific muscle is obtainable. Lower extremity activities that follow this form include leg extensions and leg curls.

Closed kinematic chain activity refers to movement that occurs concurrently in separate segments when the distal end of the limb is fixed or planted. Movement occurs both proximally and distally to teach joint of the chain. Lower extremity movements of this nature include weight-bearing...
Figure 1.—Closed and open kinematic chains.
a. A partial squat in a closed chain model.
b. A leg curl in an open chain model.
(Adapted from: Joint Structure and Function: A Comprehensive Analysis. Norkin CC, Levangie PK. 2nd ed. FA Davis Company; 1992.)
activities such as walking, squatting, leg pressing, and jumping. CKC exercises approximate functional activities more effectively than OKC exercises. Electromyographic (EMG) studies show that CKC muscle activity is similar to activities considered to be functional such as running, squatting, and walking. These activities employ composite work from many muscle groups, whereas OKC exercises isolate one muscle group.

OKC and CKC principles are at the core of lower extremity assessment and treatment. Both have been popular in clinical rehabilitation, but a concentration of treatment goals based on functional outcomes and a better understanding of biomechanics and kinesiology has increased the popularity of CKC exercises. Many other theories lend credibility to the preference of CKC activities over OKC. Biomechanically, CKC exercises are safer and potentially less threatening to healing structures. Due to increased joint compression in the CKC model, lower extremity joints receive enhanced proprioceptive input and joint stability, thereby enhancing training and evaluation performance. A result of compression may be decreased pain and joint effusion. Compression also reduces shear stress that can occur in OKC exercises, especially those at the knee joint. Shear stresses are reduced in the CKC model through cocontraction and proximal application of resistive forces. OKC activities place the resistive forces more distally. CKC activities lend themselves to coactivation of muscle groups. This is evident in the knee joint where cocontraction reduces anterior shear stress (translation of the femur
on the tibia), thus decreasing the strain on the anterior cruciate ligament.\textsuperscript{14,23-28} Another disadvantage of OKC training, at least in the lower extremity, is that it leads to increased patellofemoral compression through contact stress on the patella.\textsuperscript{5,29} Flexion moments are created at the hip, knee, and ankle joints in CKC exercises to promote stability\textsuperscript{5} (see Fig. 2). A moment, also called torque, is the product of force and distance around an axis of rotation. Lower extremity CKC activities function to decrease the knee flexion moment while increasing the hip flexion moment; thus, stability is maximized and shear stresses at the knee are minimized. Because of distal resistance in an OKC leg extension, for example, the knee flexion moment is increased leading to increased shear forces. Many of the aforementioned advantages allow CKC activities to be included in the early phases of rehabilitation programs.\textsuperscript{5} A main advantage of OKC testing is the ability to isolate a particular muscle group. This may not be beneficial since muscles do not work in isolated patterns during functional activities.\textsuperscript{16,18} CKC exercises, on the other hand, place stresses in eccentric and concentric patterns to the hip, knee, and ankle in a pattern similar to functional movements.\textsuperscript{14,30} See Table 1 for principles of CKC activities.

CKC principles are prominent in all functional testing. Functional testing allows the examiner to evaluate the strength and condition of an individual in an activity specific manner. They help assure that return to activity is in the safest and most effective way.\textsuperscript{5} Numerous lower extremity functional tests have been described in literature, including the shuttle run test,\textsuperscript{5,15,31} the sprint test,\textsuperscript{5} the
Figure 2.--Closed kinematic chain flexion moment. Closed kinematic chain exercises create flexion moments at the A, hip; B, knee; and C, ankle.

(Adapted from: Rehabilitation Techniques in Sports Medicine. Prentice WE. 2nd ed. Mosby-Year Book Inc; St. Louis, Mo; 1994.)
Table 1.—Advantages of Closed Kinematic Chain Activities

<table>
<thead>
<tr>
<th>Practical Advantages</th>
<th>Physiological and Anatomical Advantages</th>
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<tr>
<td>Concentration on functional outcomes</td>
<td>Increased joint compression</td>
</tr>
<tr>
<td>Axis of motion is not isolated to a single joint</td>
<td>Increased proprioceptive output and input</td>
</tr>
<tr>
<td>Movement occurs both proximally and distally to each joint within the chain</td>
<td>Reduced shear stress (anterior tibial translation)</td>
</tr>
<tr>
<td>Posture and body positioning can be used for stabilization</td>
<td>Reduced strain on the anterior cruciate ligament</td>
</tr>
<tr>
<td>Allows for a safe and early inclusion into a rehabilitation program</td>
<td>Minimized contact stress on the undersurface of the patella</td>
</tr>
<tr>
<td></td>
<td>Decreased pain and joint effusion</td>
</tr>
<tr>
<td></td>
<td>Coactivation of muscle groups</td>
</tr>
<tr>
<td></td>
<td>Increased joint stability</td>
</tr>
<tr>
<td></td>
<td>Decreased knee flexion moment</td>
</tr>
<tr>
<td></td>
<td>Increased hip flexion moment</td>
</tr>
</tbody>
</table>
stairs running test, the figure-of-eight test, the leg hop test, the cocontraction test, the carioca test, and the vertical jump test. The agility test incorporates quick changes in direction during maximal speed to promote controlled lower extremity rotational stresses. The shuttle run test involves running in a straight path, planting the outside foot, pivoting 180°, and returning in the opposite direction. Hopping on a specified leg for a set distance, while being timed, is the general process of a hop test. The cocontraction test is initiated by securing the individual to a resistance strap. The strap is stretched to twice the recoil strength and the subject shuffles or side steps around the outer borders of a semicircle against the resistance. The vertical jump test has been established as a determinant of explosive leg power in the lower extremity and is often used to assess dynamic force.

Evaluation of vertical jumping shows that it can be used as a practical assessment tool of lower extremity kinetic chain forces. Literature shows that jumping is an effective estimator of peak power output. Sargent's jump test relies on measuring the difference between standing reach height and touch height during the peak of a jump. It has been described as a common test to establish explosive leg power.

The leg press exercise is another method of assessing lower extremity power and strength. It takes full advantage of the kinematic chain concepts and is a valuable test of lower extremity muscle performance in a CKC model. Moreover, the leg press is used for rehabilitation and training following lower
extremity injuries.\textsuperscript{18,39} The isokinetic leg press can be a valuable CKC assessor and as stated in an article by Engle,\textsuperscript{40} "it can be a useful adjunct for the physical therapist in the overall approach to patient treatment." Studies have shown that CKC isokinetic leg press torques have shown significant relationships with OKC knee extension torques.\textsuperscript{39} The same study postulated that this relationship indicates that both tests were "assessing similar aspects of muscle performance in the lower extremity." As supported above, the isokinetic leg press can be implemented as a lower extremity evaluator.

Many studies have examined the relationship between isokinetics and functional testing. Positive correlations were demonstrated by Minkoff\textsuperscript{41} in the examination of ice skating and torque production of the lower extremity. A study following post-surgical results of partial patellar ligament ruptures found a direct correlation between quadriceps strength at low angular velocity and functional scores.\textsuperscript{42} As a functional test, the hop test has been evaluated against isokinetic results by Noyes et al\textsuperscript{43} and found to significantly correspond at lower angular velocities. Sachs et al\textsuperscript{44} found strong correlations between hamstring and quadriceps isokinetic measures with the hop index measured by a single leg hop distance. Another study by Riera et al\textsuperscript{12} compared isokinetic knee extension strength and vertical jump ability as measures of dynamic force in the lower extremities. The study found high correlation between the two measures and indicated that both can be used as valid techniques to measure power in the lower extremity musculature. Wiklander and Lysolm\textsuperscript{45} found a correlation of .84
in comparing a vertical jump test and peak torque measurements. Although the literature shows that several other studies have found direct positive correlation between functional testing and lower extremity isokinetic values,\textsuperscript{6,45-47} other studies have reported negative correlation between the two measures.\textsuperscript{15,48,49}

The majority of research evaluating the relationship between functional and isokinetic tests has performed the isokinetic portion of the study in an OKC model. Rothstein\textsuperscript{50} emphasized that because isokinetic testing is predominantly done in an OKC prototype, isokinetic results should not be used to infer functional ability. Prentice\textsuperscript{5} stated that the use of isokinetics in a closed chain model adds versatility to the clinical rehabilitation setting. The quadriceps and hamstring muscular groups of the knee are the focus in many of the OKC isokinetic studies. As indicated earlier in this review, OKC assessment can be executed to isolate muscle groups. Conversely, CKC testing represents composite muscle group performance. Clinicians are incorporating CKC isokinetic protocols in the treatment and evaluation of individuals.\textsuperscript{16,40} Some studies have recorded findings on CKC isokinetic testing, but research appears to be minimal. Levine et al\textsuperscript{16} found reliability within simultaneous hip and knee extension in a CKC position that can be comparable to OKC isokinetic findings. The study suggested that CKC principles can be incorporated into isokinetic training to provide a more functional means of measuring an individual's progress. The study also discussed the need for further testing to validate the use of CKC in the isokinetic model.
The purpose of this study is to determine a correlational relationship between standing vertical jump scores and CKC leg press measurements on a Kin-Com isokinetic dynamometer. It is hoped that the information from this study will add knowledge to the concept of CKC isokinetics as a means of functional assessment. The hypothesis to be tested is that a significant positive correlation will exist between vertical jump scores and force measurements from an isokinetic leg press. Establishing a direct relationship between these two evaluation procedures may help clinicians better ascertain the functional appropriateness of certain isokinetic tests.
CHAPTER III

METHODS

Subjects

Twenty-two healthy university students volunteered to participate in the study. Eleven females with an average age of 23 (range 21 to 26) and an average weight of 131 pounds (range 116 to 155), along with eleven males with an average age of 26 (range 20 to 37) and weight of 175 pounds (range 145 to 208) agreed to participate (see Table 2 for subject characteristics). Subjects were informed of the purpose of the study and the testing procedures and protocols prior to testing. Each subject read and signed a consent form approved by the University of North Dakota Human Subjects Review Board (see appendix).

Instrumentation

The isokinetic testing for this study was performed on the Kinetic Communicator AP dynamometer (Chattex Corporation, 101 Memorial Drive, P. O. Box 42887, Chattanooga, TN 37405). The Kin-Com is a computer-controlled electromechanical dynamometer. The Kin-Com force measurements are monitored by load cells in the level arm. The Kin-Com is able to monitor force, angle, and velocity through feedback loops which are connected to a
Table 2.—Subject Characteristics

<table>
<thead>
<tr>
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<th>Male Group (n = 11)</th>
<th>Female Group (n = 11)</th>
<th>Combined Group (n = 22)</th>
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</thead>
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<tr>
<td>Age (years)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>25.8</td>
<td>23</td>
<td>24.4</td>
</tr>
<tr>
<td>SD</td>
<td>4.9</td>
<td>1.7</td>
<td>3.8</td>
</tr>
<tr>
<td>Range</td>
<td>20 to 37</td>
<td>21 to 26</td>
<td>20 to 37</td>
</tr>
<tr>
<td>Weight (lbs.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>175.3</td>
<td>131.3</td>
<td>153.3</td>
</tr>
<tr>
<td>SD</td>
<td>20.7</td>
<td>13.1</td>
<td>28.1</td>
</tr>
<tr>
<td>Range</td>
<td>145 to 208</td>
<td>116 to 155</td>
<td>116 to 208</td>
</tr>
</tbody>
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computerized recording system. Mayhew et al\textsuperscript{4} studied the reliability of the Kin-Com by comparing the velocity, force, and angle measurements taken by the Kin-Com to the velocity, force, and angle measurements taken by an external recording system. To express interest reliability, the results of the data collection from each source must have been similar. The study also assessed the degree of between-day testing agreement of the Kin-Com measurements. Results showed high levels of agreement between days and between both sources of data collecting. These findings indicate that Kin-Com measurements are reliable and agreeable. Calibration of the isokinetic dynamometer was performed at the beginning of every test day.

Testing Procedure

All subjects participated in two sessions with an approximate time frame of one week separating the two sessions. The first session was a practice or familiarization session, which involved establishment of subject position and practice trial sets on the Kin-Com isokinetic machine. This session was to allow the subjects to become familiar and comfortable with the isokinetic leg press procedure as recommended by Wessel et al\textsuperscript{51} and others.\textsuperscript{5} This familiarity enabled the subjects to perform at an optimal level.

The final session involved the body weight measurement and testing procedures. The subjects were weighed in testing clothing (t-shirt and shorts) and shoes. A warm-up was then completed that was variable and dependent on subject preference. The vertical jump testing was then performed, followed by
the isokinetic leg press testing (which initially involved three to five trials of warm-up). The final session was completed when the body weight measurement, vertical jump test, and lower extremities isokinetic tests had all been performed. All research was supervised by one investigator to exclude any potential examiner-related variability.52

Vertical Jump Protocol

The vertical jump protocol utilized in this study was described by Miller 36 in 1988. His testing procedure was based upon early definition of the vertical jump by Sargent. Sargent’s jump test has been referred to as one of the most commonly used assessors of explosive leg power.38 Miller36 indicated that the validity of the vertical jump in testing leg power is .78, while the reliability is .93.

Prior to vertical jump testing, all subjects were allowed warm-up time which consisted of stationary bike riding, general leg stretching, and low level calisthenics. Miller36 suggested that all performers be allowed to practice the jump before administration of the test. Therefore, subjects were allowed to practice the jumping procedure before testing. Practice time was variable and dependent on subject preference.

A suspended four inch-wide vertical board was the platform upon which the jump measurement was recorded. The board was securely fastened to an overhanging apparatus. The apparatus was mounted to a wall which allowed for proper stability. A tape measure was attached to the board to create the vertical jump measurement platform.
Before jumping, the standing reach height of each subject was measured. This was done by having the subject stand directly under the measurement platform and reach up to touch the platform. When the individual was standing and reaching with a naturally erect posture (not bent, but not straining), a chalk mark was placed at the subject’s middle fingertip by the researcher to mark the standing reach height on the platform. Each individual then wiped the second, third, and fourth fingers from the distal interphalangeal joint (DIP) to the finger tips in colored chalk. Upon jumping, each subject would touch the measurement platform to give reference to the jumping height.

During testing, each subject was given a verbal and visual demonstration of the jump procedure to minimize individual differences. Each subject was allowed three to five test trials. The vertical jump procedure was initiated from a stationary position and the subjects were allowed a pause between each trial.

To initiate the vertical jump protocol, each subject positioned his/her shoulders parallel to the measurement platform. The subjects were informed to turn approximately 45° to the left or right. It was theorized that the 45° turn would allow for comfortable reaching and, therefore, optimum performance. Each individual then positioned his/her feet within a comfortable base of support (approximately shoulder width). Upon comfortable body and feet positioning, each subject prepared to jump. The jump was initiated with a downward dip into a squatting position. The squat was followed by a maximum upward thrust which was provided by leg power, arm swing, and body positioning. The continuation
of the arm swing allowed the individual to mark the board at the peak of the upward thrust. This peak mark, or vertical jump height, was then compared with the standing reach height by subtracting the distance between the two marks. As described by Miller, the distance between the two chalk marks, measured to the nearest half inch, was used as the test score. The result of the best vertical jump trial was retained for analysis.

Upon determining the most competent vertical jump procedure for this study, a number of jumping aspects should be examined. One factor that needs analysis is the use of arm swing and its contribution, if any, to vertical jump height. Ramsey found that 30% to 40% of jump height is from arm swing contribution. Al-Nashash and Al-Kurdi indicated a 21% difference in jump ability between hand fixed to the waist and hands free to move. Shetty and Etnyre discovered that maximum force, power, and release velocity were greater with arm swing. The same study also revealed findings that the impact force from jumping is significantly reduced when arm swing is utilized, thus decreasing potential for injury. Furthermore, arm movement and position aid in body balancing by reducing instability caused by ground reaction forces.

Body balancing, or control, is another key factor in vertical jump ability. Bobbert determined that muscles produce ineffective work in jumping, if jumping control is not optimal. Moreover, it was reported that a training protocol containing lower extremity muscle strengthening without an opportunity to practice the vertical jump led to decreased vertical jump performance upon
retesting. Without practicing the vertical jump, control can be lost even when muscle strength increases because of less efficient muscle control. These findings indicate that muscular strength, as well as muscle control, is important for vertical jumping.

In discussing control and strength, a muscular model can be used to define lower extremity contributions in jumping. The gluteal, hamstring, rectus femoris, vastus medialis, gastrocnemius, and soleus muscle groups represent the muscular jumping scheme (see Fig. 3). Hubley and Wells determined the work contributions of the hip, knee, and ankle muscular groups during a maximal vertical jump. They found that the dominant forces were produced by the hip and knee extensors, along with the plantarflexors. In evaluating the relative contribution of each muscular group, it was determined that the knee extensors contributed 49.7% of the jumping force, the hip extensors 28%, and the plantarflexors 23% to a maximal vertical jump. Bobbert expressed the biodynamics of these muscles in EMG studies during vertical jumping. He indicated that jumping achievement is directly related to muscle action "timing" or sequence.

In this study, the goal of the vertical jump test was to establish a measurement which could be compared with an isokinetic leg press. It was the hope of the researcher to produce a test that could be effective and consistent, moreover decreasing intersubject variability. As supported by the preceding literature, control in jumping will create an effective and reliable test. Control
Figure 3.--Schematic drawing of the musculoskeletal model used for vertical jumps. It consists of six muscle groups of the lower extremity. (HAMstrings, GLUteal muscles, m. RECTus femoris, mm VASTi, m. GASTrocnemius, and m. SOLeus).

assists in the maintenance of balance and the achievement of muscle actions. Arm swing aids in control during jumping, along with decreased impact forces that could lead to injury. For these reasons, arm swing was included in the vertical jumping procedure.

Isokinetic Leg Press Protocol

The isokinetic leg press was tested concentrically on the Kin-Com dynamometer in a seated position. The concentric velocity was set at $90^\circ$ per second. All leg press practice, warm-up, and test sets contained ten repetitions. The practice session, or initial session, was used to establish patient position and to allow each subject to perform three to five practice sets with each leg.

Before discussing the leg press procedure, a description of pertinent Kin-Com components and positions will be reviewed. The Kin-Com seat was positioned at a seatback angle of $60^\circ$, while the seat bottom was inclined $15^\circ$ from horizontal. The seat remained stationary during all subject positioning, except when switching testing sides. Another vital component is the dynamometer head. The head contains the lever arm, load cell, and footplate attachment. Force, velocity, and angle measurements are all obtained from feedback loops that originate at the Kin-Com head. The head was rotated $15^\circ$ back from vertical orientation (away from the subject). Pins were positioned to establish stopping points as described by the Kin-Com setup procedure. The footplate was attached directly into the load cell, which was located on the lever arm. Stabilization straps were placed around the waist, forefoot, and ankle.
Each subject was allowed the use of a safety button as a precautionary measure. Upon pushing of the safety button, all dynamometer movement would cease. The subjects were also informed that lifting the force from the footplate (i.e., pulling the leg back) would also stop testing.

Subject position was first established during the practice session and rechecked prior to testing in the final session. Subject position was standardized to create consistency. Initially during the practice session, each subject was asked to sit in the Kin-Com seat with the back positioned flush against the backrest. A stabilization belt was then fastened around the waist. The Kin-Com seat depth was then adjusted, if needed, to allow for full support of the thigh without causing discomfort at the popliteal space. This resulted in a knee angle of approximately 80° to 85°, with both legs hanging off the end of the seat perpendicular to the ground. The Kin-Com seat remained stationary and any necessary adjustments were made by moving the Kin-Com head. Adjustments were made in four directions: 1) away from the Kin-Com seat and subject, 2) towards the Kin-Com seat and subject, 3) up towards the ceiling, and/or 4) down towards the floor.

Following seat depth positioning, the subject extended the test leg which was positioned on the same side of the Kin-Com. The dynamometer head was either moved toward or away from the subject so that the foot could be placed into the footplate with the test leg in a slightly flexed (10° to 15°) position. The footplate was adjusted so that the metatarsal heads were in line with the
footplate axis of rotation to promote a recommended arc of motion at the ankle. Use of the rotational footplate created free moving plantarflexion and dorsiflexion in line with the knee and hip motion. This positioning allowed for optimum contribution from the plantarflexor muscles during the leg press. Stabilization straps were placed around the forefoot and the ankle to secure the foot into the footplate.

The dynamometer head was then adjusted until protocol based joint angles were obtained by goniometric measurement. The head was positioned until 20° of knee flexion was measured. Next, the hip angle was measured and found acceptable if within 105° to 110° of hip flexion. Finally, the position was saved in the Kin-Com computer for the subject if the ankle angle was found to be within 85° to 90° (5° of dorsiflexion to neutral). If any of the three joint angles were not within the designated ranges, the Kin-Com head would be repositioned and measurements would be retaken (in the same order from the knee, to the hip, and finally to the ankle) until correct angles were established. These standardized position angle became the stop position during the isokinetic leg press (see Fig. 4). The start position was determined by moving the lever arm up from the stop position for a motion arc of 55° (see Fig. 5). The 55° lever arm arc motion represented composite movement of the hip, knee, and ankle joints. After moving the lever arm upward 55°, the position was entered into the computer as the start position.
Figure 1.--Isokinetic leg press stop position
Figure 2.—Isokinetic leg press start position
After stop and start positioning was established, practice trials of ten repetitions were performed. The subjects were instructed to incrementally increase force during each trial set, until approximately 75% to 85% effort was given on the final practice set. Three to five trials were performed for practice. Subjects were encouraged to view the representative force diagrams, including numeric output and bar graph, on the Kin-Com monitor screen during all trial sets. Following completion of testing on one leg, subject position and practice trials were conducted on the other leg in the same manner. The practice session was finished when subject positions were created on both legs and practice trials were performed.

The isokinetic leg press test protocol was conducted during the final session after the completion of the body weight and vertical jump measurements. All subjects were allowed to restretch after the vertical jump testing and before the leg press testing, if so desired. Isokinetic testing for each leg was completed in a random manner with some subjects first tested on the right side, and other subjects first tested on the left side.

The isokinetic test protocol was initiated by positioning the Kin-Com head into the previously saved position for each subject. This information had been saved into the Kin-Com computer during the practice session. The subject then was positioned into the seat with the back flush against the backrest as in the practice session. The waistbelt was then fastened. The lower extremity was placed and fastened into the footplate. Information on proper footplate
alignment was also saved into the Kin-Com computer and adjusted to meet that position. Joint angles were then rechecked with a goniometer and adjusted to the previously specified angles if necessary. The lower extremity was then moved through the 55° arc of motion, after which this start position was entered into the computer. Subjects were allowed three to five warm-up sets with ten seconds of rest between each set. Proper active warm-up prior to testing has been described as a necessary testing guideline in isokinetic testing. The subjects were asked to gradually increase force production throughout the warm-up sets in preparation for the test set.

Following the last warm-up set, subjects were allowed a rest period before administration of the leg press test set. All individuals took between 30 seconds and one minute of rest during this time. The test set required ten maximal repetitions from each subject. The subjects were informed that although ten maximal repetitions were to be completed, only the best repetition would be assessed in this study. Upon receiving this information, subjects were allowed to reject a test set once or twice, if they felt that the optimal repetition was not achieved. No subject was allowed more than three test sets. The majority of the subjects reached their one maximal repetition during the first test set. As done in the practice session, subjects were allowed consistent visual reinforcement by observing the monitor screen. Knowledge of results or visual feedback has been shown to enhance performance in strength testing. Consistent and moderate verbal encouragement was also given to stimulate optimal performance as
advocated by Kelley and Clark.\textsuperscript{59} After measurement was completed on the first leg, the subject was removed from the seat, the Kin-Com was positioned for the opposite leg, and the test protocol was again followed. The isokinetic leg press test was completed when maximal force measurements were recorded into the Kin-Com computer for both legs.

In reviewing the isokinetic leg press protocol, a few parameters and positions will be discussed. Numerous studies have examined the effects of force and torque production in lower extremity musculature when body positioning was altered for isokinetic testing. Worrell et al\textsuperscript{63} determined that hamstring and quadriceps peak torque values were significantly higher in a seated position as compared with a supine position. Findings in another study by Lunnen et al\textsuperscript{64} indicated that as hip flexion increases, torque production in the lower extremity increases. In support of these findings, Worrell and colleagues\textsuperscript{63} suggested that hip flexion between 110° and 130° allowed for the most efficient actin-myosin crossbridging in the knee flexors and extensors. They indicated that a supine position of testing does not prove optimal because the rectus femoris is placed in an ineffective lengthened position and the hamstrings are positioned in an inefficient shortened position. In exploring the effects of positioning on hip musculature, Lindsay et al\textsuperscript{65} reported that a seated position produced significantly greater rotational torques in the hip than supine positioning. Analysis of the preceding findings indicate that a seated position allows for the most power efficiency in the lower extremity musculature.
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The velocity of the isokinetic testing is another factor in determining an isokinetic protocol. Research has established that as isokinetic velocity increases, force production decreases in the knee flexors and extensors.\textsuperscript{6,63,66-68} Higher correlations between isokinetic and vertical jump tests were found in middle velocities (120° to 240° per second) than in higher velocities.\textsuperscript{12} Riera et al\textsuperscript{12} explained this finding by stating that isokinetic reactive and elastic components of muscle action, specifically at lower isokinetic velocities, are similar to jumping muscle actions. Based on this information, the low to middle velocity of 90° per second was chosen for this study.

Statistical Analysis

The Pearson correlation coefficient ($r_{xy}$) was used to assess the relationship between isokinetic leg press results and a vertical jump power quotient. The power quotient of jump height multiplied by body weight was created to represent one variable ($x$) and the isokinetic leg press force measurement represented the second variable ($y$).

A second-order partial correlation coefficient was also used to determine the correlation between vertical jump scores and isokinetic leg press force measurements. Partial correlation analysis allows interpretation of correlational results while accounting for and eliminating the influences of other variables.\textsuperscript{69} A second-order partial correlation takes two variables into account. The second-order partial correlation formula can be symbolized as:

$$r_{xy \cdot Z_1 Z_2}$$
The second-order variables in this study were weight \((z_1)\) and gender \((z_2)\). Vertical jump scores are represented as the \(x\) variable and leg press force measurements are represented as the \(y\) variable.

Subject performance demographics were also calculated using descriptive statistics. All statistical analysis was two-tailed and the level of significance was set at \(p < 0.05\). All statistical analyses were performed by SPSS-X™.70
CHAPTER IV

RESULTS

Subject performance results are reported in Table 3 and Figure 6. When leg press results of the entire sample were analyzed by T-test for pairs, a significant difference was evident between left leg press and right leg press ($p < .001$) (see Table 4). Pearson correlation coefficients were significant when power quotient scores (vertical jump multiplied by body weight) were compared to left leg press ($p < .001$), right leg press ($p < .001$), and average leg press ($p < .001$) (see Table 5). However, second-order partial correlation coefficients did not find a significance between vertical jump and left leg press ($p = .220$), right leg press ($p = .059$), and average leg press ($p = .097$) (see Table 6).
<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>range</th>
<th>mean</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>Left leg press (lbs)</td>
<td>22</td>
<td>103 to 375</td>
<td>200.8</td>
<td>70.5</td>
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<tr>
<td>Right leg press (lbs)</td>
<td>22</td>
<td>114 to 429</td>
<td>233.5</td>
<td>83.4</td>
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<tr>
<td>Average leg press (lbs)</td>
<td>22</td>
<td>108.5 to 373.5</td>
<td>217.1</td>
<td>75.5</td>
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<tr>
<td>Vertical jump (inches)</td>
<td>22</td>
<td>13 to 36</td>
<td>20.3</td>
<td>5.4</td>
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</tbody>
</table>
Figure 6. Leg press force.

Average Leg Press

Right Leg Press

Left Leg Press

Pounds of Force

190 200 210 220 230 240
Table 4.—Difference Between Left Leg Press and Right Leg Press Measures

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>mean</th>
<th>SD</th>
<th>df</th>
<th>T value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left leg press (lbs)</td>
<td>22</td>
<td>200.8</td>
<td>70.5</td>
<td>21</td>
<td>-4.77</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Right leg press (lbs)</td>
<td>22</td>
<td>233.5</td>
<td>83.4</td>
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</table>
Table 5.—Pearson Correlation Coefficients Between Leg Press and Power Quotient

<table>
<thead>
<tr>
<th>Variable</th>
<th>r</th>
<th>df</th>
<th>p</th>
<th>$r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Quotient (Jump times body weight) with:</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Left leg press</td>
<td>0.7319</td>
<td>22</td>
<td>&lt;.001</td>
<td>0.5357</td>
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<tr>
<td>Right leg press</td>
<td>0.7567</td>
<td>22</td>
<td>&lt;.001</td>
<td>0.5726</td>
</tr>
<tr>
<td>Average leg press</td>
<td>0.7594</td>
<td>22</td>
<td>&lt;.001</td>
<td>0.5767</td>
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</table>
Table 6.—Second-Order Partial Coefficients for Comparison Between Leg Press and Vertical Jump

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<tr>
<th>Variable</th>
<th>df</th>
<th>r</th>
<th>p</th>
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<tbody>
<tr>
<td>Vertical Jump with</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Left leg press</td>
<td>18</td>
<td>0.2867</td>
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<td>Right leg press</td>
<td>18</td>
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<td>Average leg press</td>
<td>18</td>
<td>0.3814</td>
<td>0.097</td>
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</table>
CHAPTER V
DISCUSSION

The results of this study show that when body weight and gender were not considered variables in the Pearson's correlational testing, leg press measures were significantly related to vertical jump scores and found to be highly correlated (.73-.76). The coefficient of determination ($r^2$) value shows that 54% to 57% of the vertical jump scores can be accounted for by the isokinetic leg press results. In other words, any variability within vertical jump height can be shared by a variability in leg press force results.

On the other hand, the results of this study revealed that a significant partial correlation was not present between vertical jump scores and isokinetic leg press measurements when weight and gender were considered. According to these results, the isokinetic leg press is not a valid assessment tool of functional ability.

In the Pearson's correlation, body weight was not totally eliminated as a factor. It was, along with the vertical jump score, part of the power quotient product. This power quotient (vertical jump height multiplied by body weight) was statistically analyzed against the isokinetic leg press measurements. It was the opinion of the researcher that body weight should be included in all
statistical comparisons because it is an important variable in jumping and possibly in leg pressing ability. For example, a 300-pound person may have a comparatively strong leg press but his/her vertical jump score may be comparatively low. Body weight was statistically included to minimize any advantages or disadvantages of high or low body weight.

Although body weight was deemed an important inclusive factor in this study, possibly a more pertinent component could have been lean body mass. Lean body mass, in measuring muscle versus fat percentages, may be better equipped to standardize the effects of body weight on vertical jumping and leg pressing ability. Because the vertical jump and leg press tests are evaluators of lower extremity power and muscle performance, lean body (muscle) mass would have been a more valid appraiser of body weight influence on these tests. Future studies that deem body weight an important factor might consider using lean body mass as opposed to absolute weight measurement.

An interesting finding based on isokinetic results of the whole sample was the significant difference in the left leg press measures and the right leg press measures. The left leg press mean was 201 pounds of force, whereas the right leg press mean was 233 pounds of force. A significant difference (p < .001) was established between left and right leg press. Although five of the 22 subjects recorded similar force production within 15 pounds between each leg, nine subjects recorded differences of greater than 40 pounds of difference between
legs. In fact, one subject produced a difference of 120 pounds. Only three subjects produced higher force with the left leg press.

In looking at possible causative factors of this difference, side dominance must be examined. Dominant side was not officially examined in this study, but by evaluating the vertical jump, it was evident that 20 of the 22 subjects touched the vertical jump platform with the right hand. It was evident that the majority of subjects in this study were right-side dominant, but whether this finding alone accounts for the significant difference in force production between each leg is in doubt.

A noteworthy occurrence during isokinetic testing was the subjective observation that the lever arm did not always travel through the full user-set arc of motion. This study did not objectively measure this finding, but Mayhew and associates have also noted losses of lever arm motion during low and medium velocity testing. They indicated that although the loss never exceeded 4°, problems may be created in the acquisition of isokinetic measures. A subjective complaint in approximately 50% of the subjects was that the left leg press arc of motion was not as great as the right leg press range of motion. Although isokinetic procedures were duplicated exactly on each side, this fraction of the subjects felt that less flexion was achieved at the start position on the left leg during testing. The length-tension curve explains that as a muscle is placed into higher degrees of stretch without exceeding physiological limits, concentric force production increases with muscle action. Greater force capacity occurs
because of optimal action-myosin crossbridging in a lengthened muscle. These facts taken together may explain some of the reasons for significantly higher force production with the right isokinetic leg press in light of possible reduced motion in the left leg press.

Leg press evaluation on the isokinetic dynamometer would be optimal if both lower extremities would be tested at the same time. Assessment of both legs simultaneously would eliminate any between leg differences. Results would have also more closely corresponded to the bilateral vertical jump test that was used in this study. A bipedal footplate attachment is presently not available on the Kin-Com. Moreover, Kin-Com maximum force capacity would not accommodate double leg forces at certain velocities. In this study, at 90°/second, one subject reached 429 pounds of force and other subjects reached the mid to upper 300 pound level. The maximal force capacity for the Kin-Com AP is 450 pounds. It is evident that bilateral isokinetic leg press testing would provide optimal and potentially reliable assessment, but the isokinetic machines are currently not adapted for this type of measurement.

The lack of acceptable correlation between the isokinetic testing and vertical jump testing may not only be due to isokinetics, but also partially or completely due to the chosen functional test. The vertical jump has been described as a practical assessment tool of dynamic leg press force. On the other hand, Risberg et al stated that the vertical jump test may not be recommended as a lower extremity functional test because of test-retest
variability. Many other functional tests have been described as lower extremity assessment tools including sprinting, agility, hopping, jumping, and cocontraction tests.\textsuperscript{5,15,31-33,47}

In an attempt to establish positive correlation between functional tests and isokinetic testing, many studies have compared results from both evaluative techniques.\textsuperscript{6,41-47} Although a statistically significant relationship was found, it is evident that these studies compared CKC functional testing to OKC isokinetic testing. Because CKC exercises have a greater functional basis than OKC exercises, it has been suggested that information on CKC isokinetics is needed.\textsuperscript{14,16}

Perhaps to truly compare a CKC isokinetic leg press to functional testing, a more complete correlational analysis should involve a variety of functional tests. By comparing the isokinetic leg press to numerous functional tests, a more precise representation of the isokinetic leg press as a CKC functional assessment tool may be obtainable.
CHAPTER VI

CONCLUSION

Isokinetics and functional testing are useful for the evaluation of lower extremity performance. Comparisons have been developed between functional testing in a CKC model and isokinetic testing in a OKC model to establish clinically relevant relationships. CKC activities create movement in the lower extremity that is in a coinciding pattern to functional movements. It has been suggested that CKC isokinetics can be incorporated into training and assessment to facilitate a more functional means of measuring an individual's progress.

This study proposed to assess the relationship between two CKC activities that utilize similar lower extremity musculature, the isokinetic leg press and vertical jump test. It may be concluded from this study that a significant positive correlation did not exist between vertical jump scores and isokinetic leg press force results for which weight and gender were accounted. However, a highly positive correlation existed when isokinetic leg press results were compared to a power quotient of vertical jump height multiplied by body weight. Another notable finding revealed that a significant difference existed between left leg press and right leg press measurements.
Taken together, the results of this study divulge that the isokinetic leg press may not be appropriate in examining functional ability. Despite these findings, isokinetics, along with functional testing, may provide a necessary adjunct to lower extremity objective and quantitative assessment that, if available, can be utilized. However, isokinetic testing may not provide the definitive activity specific assessment that is integral in return to activity evaluation.
APPENDIX
The abstract: (limit to 200 words or less and include justification or necessity for using human subjects.)

The use of isokinetic machines, such as the Kin-Com A-P, for clinical rehabilitation of injuries or pathologies is common in many physical therapy settings. Questions and concerns have been raised about the functional or activity specific reliability of gains achieved on the isokinetic machines. This study proposes to evaluate possible correlations between related strength measurements on a Kin-Com A-P and a functional strength test. Subjects will be asked to perform stationary vertical jumps and maximal repetitions of a leg press exercise on the Kin-Com. The vertical jump and leg press are common strength/power measurements that utilize much of the same musculature. The vertical jump measurements and the leg press force measurements will be compared to determine if a relationship exists. The purpose is to determine to what degree isokinetic measurements are related to functional test scores. The determination of this relationship, will enable clinicians to better ascertain the functional appropriateness of an isokinetic test for activities of this nature.
This project will involve the use of a Kin-Com isokinetic machine for one measurement, and the height of a vertical jump for a second measurement. Subject weight will also be measured and included with the output information from the Kin-Com to create a power quotient. This power quotient will be the final measure against which the vertical jump will be compared. All data presented in this project will be based on the assessment and evaluation of these measures. A proposed 20 to 40 subjects will be divided into an equal gender ratio. Each subject will be asked to perform three to five trials of a vertical jump and ten repetitions of a maximum concentric leg press exercise on the Kin-Com. Body weight will also be measured. One week prior to the final session, each subject will be asked to participate in a trial session. This session will allow the subject to become familiar and comfortable with the Kin-Com isokinetic machine. In turn, optimum effort will be put forth by all individuals.

The first procedure will involve the measurement of the maximal vertical jump. Each subject will be given three to five trials. Each trial will be taken from a stationary position and the individual will be allowed a pause or rest between jumps. An individual will be instructed in vertical jump procedure to minimize individual differences. The procedure will initially involve planting the feet shoulder width apart. When ready the subject will then bend into a squat position to be followed by maximum upward thrust. This thrust will be provided by leg power, arm swing, and general body positioning. The maximum vertical jump measurement will take place at the peak of this thrust.

The Kin-Com isokinetic machine will be positioned for a leg press function. This leg press function will allow for maximum power from the lower extremity musculature of the hip, knee, and ankle extensors. The general subject position will be horizontal with a reclined seat set-up. The beginning position for the leg press will be precisely measured on each individual to typify the squat position of the vertical jump. The beginning position angles will be 15 to 20 degrees at the knee and 100 to 110 degrees at the hip. The foot plate axis will be placed to allow for optimum ankle musculature involvement. The end position for movement will be set so that the lever arm of the Kin-Com will follow a motion arc of 55 degrees. The lever arm will demonstrate a composite motion of the hip, knee, and ankle. Fifty-five degrees has been established because it allows for full range of the legs, while preventing hyperextension at the knee joint. The test itself will involve ten consecutive maximum repetitions of each leg. The repetition that demonstrates the greatest force on the right leg, will be averaged with the greatest force repetition of the left leg. This average measurement will then be placed in the power quotient equation. A value that emerges will then be analyzed against the highest vertical jump to establish statistical correlation.

The harmful risks in this study will be no greater than those present in athletic participation, fitness training, or leisure activities. The main risk may be post-exercise muscle soreness occurring mainly in the ten maximum repetitions of each leg. The remote possibility of minor muscle strains will also be present. Subjects will be allowed general warm-up stretching time to prevent or minimize muscle strains or soreness. Subjects will also be required to wear proper footwear to lessen the remote chances of foot or ankle injuries that can occur when performing a vertical jump. When taking the vertical jump, subjects will be given adequate room to jump and land. On the Kin-Com, range of motion will be limited enough to eliminate the possibility of hyperextension and excessive stress on the joints.
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 by my advisor, Mark Romanick in the Department of Physical Therapy, Room 143, Medical Science for a period of two (2) years. A copy of the consent form is attached.

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: __________________________

Paging or Center Grant Director

DATE: __________________________
INFORMATION AND CONSENT FORM

You are invited to participate in a study conducted by Dave Silkey, a Graduate Student in the Physical Therapy Department at the University of North Dakota. The purpose of this study is to determine the relationship between a vertical jump measurement and a force measurement taken from a leg press exercise on a Kin-Com isokinetic machine. A Kin-Com is an exercise machine that is often used in clinics for rehabilitation and assessment of muscle function. You will be asked to perform standing vertical jumps and leg press exercises. I hope to establish the correlation, if any, between these two strength measurements.

You will be asked to perform three to five trials of the vertical jump and 10 repetitions of the leg press on each leg. Your body weight will also be measured and combined with the force measurement from the Kin-Com to create a power score for which the vertical jump will be compared. The vertical jump will be taken from a stationary position, and with your feet shoulder width apart, you will be asked to squat down and jump upwards. The leg press will involve pushing a foot plate while in a horizontal seated position.

The study will involve two sessions. The first will require 15 minutes to one-half hour of your time. This session will involve practicing the leg press exercise so you can become familiar with the Kin-Com. The final session will take approximately one-half hour to one hour and it will involve the measurement of the vertical jump and leg press. You will be asked to report to the Physical Therapy research lab in Medical Science North at an assigned time. You will be asked to change into gym clothes and shoes.

The vertical jump measurement will be determined by recording your height at the peak of the jump. The leg press force you create on the Kin-Com will be recorded into a computer that is part of the machine. These force measurements will be stored on the computer and later analyzed.

For each of the two sessions you will be allowed to stretch and warm-up. Following the warm-up at the practice session, you will be positioned into the Kin-Com and run through some leg press exercises. Following the warm-up at the final session, you will initially be weighed. Then, you will complete the vertical jump trials followed by the leg press repetitions.

Testing of physical activity and strength always involves some degree of risk, although the investigator feels the risk of injury is minimal. The activities in this project are controlled to reduce the possibility of injury, such as muscle soreness and muscle strain. The number of repetitions you will be asked to complete will be minimal compared to an actual exercise workout.

Your name will not be used in any reports of the results of the study. Any information that is obtained in this study and be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified with a number known only by the investigator. Your decision whether or not to participate will not prejudice your present or 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 is available to answer any questions you have concerning this study. In addition, you are encouraged to ask questions concerning this study that you may have in the future. Questions may be asked by calling Dave Silkey at 701-0-9077 or his advisor Mark Romanick at 701-777-2831. A copy of this consent form is available to all participants in this study.

In the event that this study 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 payor, if any.

I, the participant, have been answered and I am encouraged to ask any questions that I may have concerning this study in the future. My signature indicates that, having read the above information, I have decided to participate in the study.

[Signature]
[Date]

[Participant's signature]
[Date]

[Witness (not the scientist)]
[Date]
CONSENT FOR TAKING AND PUBLICATION OF PHOTOGRAPHS

Name: Gail Garrett  
Place: University of North Dakota - Physical Therapy Department  
Date: November 12, 1995

In connection with David M. Silkey's Independent Study entitled, "A Relationship Between Vertical Jump Scores and Peak Force Measurements of an Isokinetic Leg Press," consent that photographs may be taken of me and may also be used for publication under the following condition:

1. The photographs taken shall be used if the researcher, David M. Silkey, deems that medical research, education, and science will be benefited by their use. Such photographs may be published and republished, either separately or in connection with each other, in professional journals or medical books; provided that it is specifically understood that in any such publication I shall not be identified by name.

2. The aforementioned photographs may be modified or retouched in any way that the researcher, David M. Silkey, may consider desirable.

Signed ____________________________
Gail Garrett

Witness ____________________________
Stephanie Jones
Dave Silkey  
c/o Mark Romanick  
UND Physical Therapy Department  
P.O. Box 9037  
Grand Forks, ND 58202

November 30, 1995

F.A. Davis Company  
Editorial Department - Attn. Jean-Francois Vilain  
1915 Arch St.  
Philadelphia, PA 19103

Dear Jean-Francois Vilain:

I am a graduate student at the University of North Dakota working on an Independent Study entitled, "A Relationship Between Vertical Jump Scores and Peak Force Measurements of an Isokinetic Leg Press." I would like to use a figure from the book "Joint Structure and Function: A Comprehensive Analysis"(Norkin CC, Levangie PK. 2nd edition. 1992.). The figure will be used in the literature review portion of my Independent Study which is being completed as part of the requirements to earn a Master's in Physical Therapy degree.

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Thank you for your cooperation in this matter and please feel free to contact me or my advisor, Mark Romanick, at the above address if you have any questions.

Sincerely,

David M. Silkey


Name ___________________________ Date 12/3/95
November 30, 1995

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David M. Silkey

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