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A Comparison of the Maximal Torque Production of the Quadriceps Muscle during Morning and Afternoon Strength Assessment

Denise Willardsen
University of North Dakota

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A COMPARISON OF THE MAXIMAL TORQUE PRODUCTION
OF THE QUADRICEPS MUSCLE DURING MORNING AND
AFTERNOON STRENGTH ASSESSMENT

by

Denise Willardsen
Bachelor of Science in Physical Therapy
University of North Dakota, 1998

An Independent Study

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota

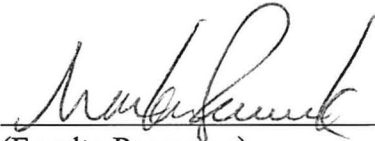
in partial fulfillment of the requirements

for the degree of Master of Physical Therapy

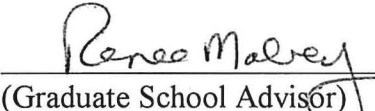
Grand Forks, North Dakota
May
1999



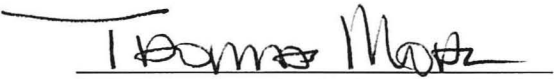
This Independent Study, submitted by Denise Diane Willardsen in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done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



(Faculty Preceptor)



(Graduate School Advisor)



(Chairperson, Physical Therapy)

PERMISSION

Title A Comparison of the Maximal Torque Production of the Quadriceps
Muscle During Morning and Afternoon Strength Assessment.

Department Physical Therapy

Degree Master of Physical Therapy

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Signature *Denise Willardson*
Date *December 3, 1998*

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This paper is dedicated to my parents and their unconditional love and dedication. They continually inspire me to do my best in whatever I attempt. I am only beginning to realize the wonderful effects they have had on my life. My Dad was right; the older I get, the smarter they become! I love you, Denise.

I would also like to offer a special thank-you to my three research partners, Shawn Docktor, Michael Rexin, and Shawn McCoul, and my preceptor, Mark Romanick, M.P.T. They are very intelligent individuals and it was a pleasure to work with each of them. In addition, I would like to thank all of our subjects for their voluntary cooperation. Their time and effort is greatly appreciated for the development of further clinical advancement through research.

ABSTRACT

The purpose of this study was to compare maximal quadriceps torque production in morning hours (AM) to maximal quadriceps torque production in afternoon hours (PM). Thirty healthy male subjects between the ages of 19 and 45 were tested during an AM and a PM session on the Kin-Com dynamometer. A trial of six concentric isokinetic contractions of the right quadriceps were tested at a speed of 60°/s. The maximal peak torque measurements were compared between the AM and the PM sessions to establish the accuracy of results taken at differing times of the day. No significant difference in strength assessment due to the time of day of assessment was found. The data collected in this study indicates that clinical assessments of maximal peak torque production can be achieved without bias to the time of day the exercise is performed.

CHAPTER I

LITERATURE REVIEW

Assessment and reassessment are two crucial components of a physical therapist's treatment procedure. Often, certain tools and procedures are used to obtain objective, measurable data to assist the therapist in the assessment/reassessment process. The instrument can only be regarded as effective, though, if a certain amount of reliability and validity are established. The apparatus or technique must be able to demonstrate both a level of consistency and a degree to which the instrument or tool is able to measure what it was designed to measure.¹ As the reliability and validity of these assessment tools increase, so does the ability of the physical therapist to treat the patient effectively; thus, the quality of patient care also increases.

One assessment technique used for clinical evaluation of areas such as exercise performance or injury progression is muscular strength assessment. Strength assessment can be evaluated by the clinician's physical assessment, known as manual muscle testing (MMT), as described in *Daniels and Worthingham's Muscle Testing: Techniques of Manual Examination*, 6th edition,² or through the use of dynamometers, hydraulically driven, micro-controlled devices designed to measure torque and work during eccentric and concentric isokinetic loading. This study analyzed measurements of muscular strength

collected on the Kinetic Communicator (Kin-Com, model 125AP with software version 4.06, Chattecx Corp., Chattanooga, TN) dynamometer. A dynamometer was chosen for data collection due to its ability to produce mathematical data (maximal peak torque measured in ft-lb) for ease of comparison.

Although many studies have been conducted that provide valuable information on the reliability and validity of strength assessment, it must be recognized that the data was derived from controlled situations. A study by Tredinnick and Duncan³ focusing on intertest reliability of concentric torque resulted in an interclass correlation coefficient of .89 using the Kin-Com dynamometer at 60°/s. This data is very impressive, but the article also specifically stated, “Each test session took place on the same day of the week and the same time of the day...” It is necessary, under research conditions, to provide for controlled situations. The consistency of time of day prevented any fluctuation in results stemming from circadian rhythms or overall subject fatigue due to previous daily/nightly activity or inactivity. Although this is standard procedure for research, the clinical aspect is not well represented. Patients are not always able to be seen by a therapist at exactly the same time each session. This study was conducted to assess the reliability of strength testing during sessions performed at different times of the day, specifically morning (AM) and afternoon (PM) sessions, which best represent the span of time physical therapy clinics are typically open for appointments.

Time of day has been theorized to affect the performance of individuals. This theory is based on the idea of circadian rhythms or biological functions that change cyclically over a 24-hour period.⁴ It is believed that all mammals exhibit these daily

rhythms which are primarily controlled by a circadian pacemaker located in the suprachiasmatic nuclei of the hypothalamus.⁵

One of the physiological events involved in human circadian rhythms is the release of ACTH (adrenocorticotrophic hormone), a pituitary hormone that stimulates the cortex of the adrenal glands to produce adrenocortical hormones. One such hormone is cortisone, important for its regulatory action in metabolism of fats, carbohydrates, and proteins. It is also used as an anti-inflammatory agent.⁶ Throughout the day, ACTH is secreted in bursts which results in a rise or fall in plasma cortisol. These bursts are most frequent in the early morning as 75% of the daily production of cortisol occurs between 4:00 and 10:00AM. These bursts are not thought to be due to the stress of getting up in the morning, though, as increased ACTH secretion occurs before waking.⁷ Cortisol decreases throughout the day, at rest, and during exercise.⁸

Body temperature follows a circadian rhythm of higher temperatures in the evening and lower temperatures in the early morning. Normal diurnal variation of body temperature is about 0.5°C with a minimum temperature reached from 5:00 to 6:00AM and a maximum temperature achieved at about 4:00PM (numbers independent of external temperature or activity).⁸ Optimal muscle performance is achieved at a temperature of 38.3°C, which is easier to achieve in the late afternoon than in the morning hours.⁹

The circadian rhythm for exercise heart rate follows the same pattern as body temperature but peaks slightly earlier in the day.⁹ Findings for exercise blood pressures found no significant difference in systolic blood pressure with the exception that afternoon (4:30PM) blood pressures at rest were lower than morning (8:30AM) resting blood

pressures. Diastolic blood pressures and rate of perceived exertion measures showed no significant differences throughout the daily circadian cycle.¹⁰ These data suggest that the existence of internal rhythms should be recognized by any individual interested in accurately measuring fitness levels or injury progression.

Data on the effects of time of day and exercise performance vary dramatically. The data collected by Galliven et al¹¹ suggest that, “metabolic and hormonal responses to short-term, high-intensity exercise can be assessed with equal reliability in the AM and PM.” In a study on prolonged exercise, Reilly and Garrett¹² determined that a higher power output occurred in the evening over the first 30 minutes of the test but was compensated for by a greater performance in the morning over the second 30 minutes ($p < .05$). Their conclusion was that pacing of endurance performance was affected in the morning, but there was no overall effect for the duration examined. Trine and Morgan⁸ state the performance of physical activity is generally improved in the afternoon or evening, compared with morning. In addition, Reilly and Baxter¹³ tested high intensity aerobic effort and found exercise tolerance time, total work done, and peak lactate production were significantly greater in the afternoon. They concluded that superior exercise performance in the evening may be attributed to a greater tolerance for high intensity exercise.

The idea of training specificity has also been considered in the idea of circadian rhythms. Hill et al¹⁴ found that subjects who trained in the morning had higher posttraining results in the morning, while training in the afternoon resulted in higher posttraining results in the afternoon. The relevance of this study pertains to the effects of

physical preparation to coincide with the time of day at which one's evaluation of performance is expected (i.e. theoretically, consistent rehabilitation sessions for anterior cruciate ligament tears in the PM will result in higher Kin-Com evaluation scores for a test performed in the PM). Due to the variability of the present data on circadian rhythms and its effect or lack of effect on exercise performance, the necessity for accurate information on objective measurements of exercise performance are apparent.

The purpose of this study is to compare maximal quadriceps torque production in morning hours (AM) to maximal quadriceps torque production in afternoon hours (PM). By establishing the accuracy of results taken at differing times of the day, clinical assessments of exercise performance or injury progression can be achieved without bias to the time of day the testing was performed. The significance of valid and reliable data for strength assessment is imperative to portray accurate fitness level or injury recovery progression.

The null hypothesis for this study is that there is no significant difference in maximal quadriceps torque production in the AM compared to maximal quadriceps torque production in the PM. If this is true, strength assessment can be performed throughout the day to accurately measure and compare muscle torque production regardless of the time of day the previous testing was performed.

The alternate hypothesis, though, is that the maximal quadriceps torque production in the AM is significantly different than the maximal quadriceps torque production in the PM. Data supporting the alternate hypothesis suggests a need for testing sessions to be consistent in the time of day given for accuracy of test results.

Continual research is necessary to establish protocols for the most efficient and precise data collection in physical enhancement and rehabilitative settings. This data is useful to many facets of health care including the patient, the therapist, the physician, insurance companies, the employer, and the researcher.

CHAPTER II

METHODS

Subjects

Thirty healthy male subjects between the ages of 19 and 45 participated in this study. The subjects represented variable physical activity levels from minimal daily exertion to intense recreational activity. All subjects were volunteers from the University of North Dakota. Prior to data collection, approval for the procedures used in this study was received from the Institutional Review Board (IRB) at the University of North Dakota (See Appendix A). In accordance with the IRB at the University of North Dakota, all subjects were fully informed of the procedures and completed a statement of informed consent (See Appendix B) before participation in the study was allowed. Subjects with a history of neurological disorders, previous leg/knee trauma within the last year, or current knee dysfunction were excluded from the study. In addition, subjects who report any muscle fatigue or weakness due to activity prior to the testing time were also excluded from the study.

Instrumentation

Kinetic Communicator Dynamometer

The equipment used to evaluate the peak torque in this study consisted of the Kin-Com (model 125AP with software version 4.06, Chattecx Corp., Chattanooga, TN) dynamometer. A dynamometer is a hydraulically driven, microcomputer-controlled device designed to measure torque and work during eccentric and concentric isokinetic loading.³ Torque refers to the ability of any force to cause rotation of a lever. It is a product of the magnitude of the applied force and the distance that force lies from the axis of rotation.¹⁵ In relation to the dynamometer, torque is the product of the muscle force measured at the resistance pad multiplied by the pad's distance from the axis of rotation. The distance from the pad to the axis of rotation is entered into the computer for each individual subject before the testing begins.¹⁶ The dynamometer is capable of measuring the precise amount of torque generated by supplying a graded resistance to the limb that is attached to the machine's lever arm. The graded resistance occurs when the lever arm reaches a predetermined speed that is selected by the operator. This graded resistance remains throughout the range of motion as long as the speed remains at the set level; speeds above the maximal level are prevented by the resistance the device provides.¹⁷ Peak torque is the highest torque produced at one point in the range of motion.¹⁸ Work is accomplished when a force is applied to an object in the direction of motion of the object. The magnitude of work is directly proportional to the applied force and to the magnitude of movement produced. Work equals force times distance.¹⁵

The dynamometer is one of the unique machines that is able to assess isokinetic muscle contractions. In isokinetic exertion, both eccentric and concentric, the angular

velocity of the muscle is held constant by the mechanical device throughout the range of motion. The resistance produced by the machine is directly proportional to the torque produced by the involved muscle at all points in the range. As the muscle torque increases, the resistance proportionally increases.¹⁵ The two types of isokinetic contractions assessed by the dynamometer, eccentric and concentric, are differentiated by the muscle action. In both types of contraction, the muscle is exerting a force. During a concentric contraction, work is achieved as the muscle moves the body part in the direction of the muscle pull. The muscle shortens as it contracts. During an eccentric contraction, the force generated by the muscle is exerting a force less than that of the lever. The muscle will lengthen as it contracts.¹⁵

The reliability and validity of the Kin-Com to assess isokinetic torque during successive sessions has been established in several previous studies. Snow and Blacklin¹⁶ found that within sessions, the interclass correlation coefficients (ICC) ranged from .94 to .98 for 30°/s and from .92 to .97 at 180°/s. Between sessions trials (1 week apart) ranged from .94 to .98 for 30°/s and from .75 to .88 for 180°/s. The data represents a higher reliability for slower speeds. In an analysis of the reliability and validity of the kinetic communicator exercise device by Farrell and Richards,¹⁹ both static and dynamic tests resulted in a difference of 3.2% or less for force measurements and were felt to be due to calibration error and not an indication of inaccuracy in the Kin-Com system. A study by Reitz et al²⁰ reported a correlation coefficient for the Kin-Com ranging from .95 to .98 for parameters of 60°/s, 120°/s, and 180°/s. The work of Tredinnick and Duncan³

resulted in an interclass correlation coefficient for intertest reliability of concentric torque at 60°/s to be .89.

The dynamometer is a versatile machine that is capable of testing both the upper and lower extremities. It can be set in either an evaluation mode or training mode.²¹ In this study the right lower extremity concentric isokinetic contractions were tested in the evaluation mode. The range of motion (ROM) for the lever arm was set to an anatomical zero for each subject. From that point the machine was programmed to allow for motion of testing between 10° and 80°. The acceleration and deceleration settings of the Kin-Com lever arm at end range were set on high. The high settings allowed for the subject's limb to accelerate and decelerate from a constant velocity in the shortest possible time period, thus maximizing the amount of time the subject's limb moved at a constant velocity.²¹ The velocity of the lever arm was set at 60°/s. This speed was selected due to reports from previous studies that suggest a high correlational coefficient (.89) for concentric torque at this speed.³ This data has also been reinforced by Snow and Blaklin⁶ who concluded that slower speeds reveal a higher rate of reliability. In addition, this speed is commonly used in clinical settings to assess patient progression.

Other Equipment Used

Other equipment used during testing consisted of a standard stopwatch used to time warm-up activities and breaks between practice and actual test, a calibrated scale to measure each subjects weight, and a stationary Monark bicycle provided by the Physical Therapy Department to facilitate warm-up activities before isokinetic testing.

Procedure

Each subject was required to attend three sessions, one familiarization session and two testing sessions. All sessions began with a two minute warm-up on a stationary bicycle at a moderate pace. This was included to increase blood flow to the quadriceps musculature in preparation for exercise and to reduce the risk of injury.

The familiarization session was conducted for two main reasons. First, the subject would have an opportunity to become accustomed to the machine before results would be recorded. A study by Kues et al²¹ indicated that subjects reached their greatest peak torque on sessions two or three for all conditions. No data was recorded until the familiarization session had taken place, therefore, all data collection was performed during the second or third session. Inconsistencies would be minimized due to subject accommodation to the machine. Second, the session allowed for seat placement adjustment to fit the subject's body size, shin placement pad assessment, and angle placement of the seat to align the axis of lever arm with the subject's knee. All of this data was recorded in the computer and recalled for consistency between sessions.

Each subject was positioned in a seated posture in the Kin-Com machine. The popliteal fossa of the right knee was approximately 1 to 2 in from the seat edge when the back was flat against the chair back, allowing for adequate knee flexion without soft tissue compression. Three belt restraints (two diagonal chest and one lap) were used to avoid influence of trunk motion on the test results.³ In addition, a thigh stabilizer was applied to the right upper thigh for stability. The subjects were instructed to rest their hands on their lap thus preventing anchoring of the upper extremity and inconsistency during testing sessions. The axis of the rotation of the lever arm was set in alignment

with the lateral femoral epicondyle of the right lower extremity and the lever was aligned in a parallel position with the subject's lower leg. A shin pad was attached with a velcro strap immediately superior to the lateral malleoli. The distance from axis to shin pad placement, taken from a premeasured distance chart attached to the lever arm, was entered into the computer during the familiarization session and held constant in subsequent sessions. Anatomical zero and ROM ranges (10° to 80°) were entered into the computer during each individual session. Two teams of examiners conducted the testing sessions. Prior to subject use, the team members conducted a training session and established a written protocol for testing procedure. The protocol was strictly followed by all four individuals conducting the study.

Following the collection of data on precise setup for each individual subject, the familiarization session proceeded as an actual testing session. The subject was given a "kill switch" and informed to activate the switch if at any time he was uncomfortable with the procedure. Upon activation, the kill switch would immediately stop the trial currently being performed. The subject was then instructed to perform a trial run. This was incorporated to allow the subject an opportunity to become reacquainted with the machine and become accustomed again to the available range of motion for torque measurement. Also, if any position changes were required or strap readjustments were needed, these could be performed before data was collected. The subject was then given verbal instructions that he was to kick his knee toward an extended position with as much force as possible. Once the knee achieved the predetermined range of extension, all muscle energy was to be ceased and the machine would return the limb to the start position. The ROM was set at 10° to 80° to allow for fluid movement of the device. The

investigators reported that no subjects experienced any problems with fluidity of dynamometer arm movement during data recording sessions. The speed of $60^\circ/\text{s}$ was held constant for each session for consistency. Each trial consisted of six repetitions. This frequency was chosen as a result of data collection by Kues et al²¹ indicating that the greatest peak torque values are achieved by the fifth or sixth contraction. After the sixth repetition of the trial run, the subjects were given a timed 30-second rest period. Once that time had elapsed, the subjects were instructed to perform the same procedure as they had before with the exception that the data would be recorded with this trial as if it were an actual testing session (no data was recorded during the familiarization session). After six repetitions, the subject was released from the belt restraints and assisted off of the machine seat.

After the familiarization session, the subjects were randomly assigned to one of two groups, one ($n=15$) of which was tested in the morning hours (AM) during their first session and in the afternoon hours (PM) during their second testing session. The other group ($n=15$) was tested during their first session in the PM and the second session was conducted in the AM. An AM session was defined as a session conducted no longer than 1.5 hours after the subject awakened from a 6-hour or longer sleep. A PM session was defined as a session conducted after the subject had been awake for longer than 8 consecutive hours but no more than 16 consecutive hours. The titles of AM and PM can be accurately used since all morning trials were conducted before noon, and all afternoon trials were conducted after noon. These steps were taken to ensure the data was not skewed due to familiarization of the machine. The sessions were scheduled at least three days apart for adequate rest between sessions.

The two testing sessions were conducted exactly as the familiarization session with the exception that the setup data was recalled from the computer for each subject to maintain consistency. In addition, the test results were recorded and stored in the computer's database. When not in use, the computer was kept in a locked room for confidentiality of data.

Data Analysis

The right quadriceps muscle of each subject was measured for the highest peak torque during a set of six concentric isokinetic contractions at 60°/s. These values were identified using the Kin-Com software. The highest peak torque value for each test, one for the AM session and another for the PM session, were recorded for each subject. The group mean, standard deviation, and range were determined for each test session. Ratios comparing the AM and PM session were also analyzed. Descriptive statistical methods were used to describe the data with the use of a t-test for paired samples. In addition, Pearson's Correlation analysis was performed. All of the above data interpretations were analyzed for the entire sample and for two groups. Group I consisted of 15 subjects who participated in an AM session for their first recorded trial. Group II consisted of 15 subjects who participated in a PM session for their first recorded trial.

CHAPTER III

RESULTS

As mentioned in the Methods, the subjects performed two separate recorded trials, one in the AM and one in the PM. The maximal peak torque value (ft-lb) for each subject was determined by the highest torque produced during each six repetition trial at 60°/s. The mean value for the maximal peak torque production in the AM trials was 185.1 ft-lb. The mean value for the maximal peak torque production in the PM trials was 186.6 ft-lb. For the group (n=15) who performed their first recorded trial in the AM, Group I, the mean value of maximal torque production in the AM was 184.6 ft-lb and 181.6 ft-lb in the PM. The mean value of maximal torque production for the group (n=15) who performed their first recorded trial in the PM, Group II, was 185.7 ft-lb in the AM and 191.7 ft-lb in the PM. Additional data is presented in Table 1.

Sample	Mean (ft-lb)		Standard Deviation		Range (ft-lb)		AM / PM Ratio
	AM	PM	AM	PM	AM	PM	
Entire Sample (n=30)	185.1	186.6	35.6	41.1	122-273	123-286	0.99
Group I (n=15)	184.6	181.6	31.3	38.9	122-241	129-249	1.02
Group II (n=15)	185.7	191.7	40.6	43.9	129-273	123-286	0.97

The AM / PM ratios indicate that there was no significant difference between the two trial times as they all are nearly a 1:1 ratio. This data is reinforced by the use of a t-test for paired samples which revealed that the mean peak torque values were not significantly different for the sample ($t(29) = -.46$, $p < .05$, two-tailed). In addition, Group I ($t(14) = +.52$, $p < .05$, two-tailed) and Group II ($t(14) = -2.14$, $p < .05$, two-tailed) both failed to display any significant difference between tests performed in the AM and the PM. Data from the t-test for paired samples is presented in table 2.

Sample	t
Entire Sample (n=30)	-0.46
Group I (n=15)	+0.52
Group II (n=15)	-2.14

Calculations using the Pearson's Correlation revealed extremely high coefficients. The correlations ranged from .82 to .97. Table 3 contains the correlations between AM and PM sessions for the entire sample as well as for each group.

Sample	Correlation Value
Entire Sample (n=30)	0.90
Group I (n=15)	0.82
Group II (n=15)	0.97

CHAPTER IV

DISCUSSION

The results of this study indicate that during concentric isokinetic contractions on a Kin-Com dynamometer at a speed of 60°/s there is no significant variation in the maximal peak torque measurements taken during AM and PM testing sessions (mean difference of 1.5 ft-lb). This data does not reinforce the theory that time of day for dynamometer strength testing is influenced by circadian rhythms or overall subject fatigue due to previous daily/nightly activity or inactivity. In addition, the data does not appear to be skewed due to subject accommodation to the machine or learning affect. This is supported by an analysis of the data that compared the mean peak torque values for each randomly selected group. (Group I consisted of 15 subjects who participated in an AM session for their first recorded trial. Group II consisted of 15 subjects who participated in a PM session for their first recorded trial.) The mean differences between Group I and Group II were 3.0 ft-lb and 6.0 ft-lb, respectively. For each group, the higher mean was attained during the first recorded session.

Although the data does not support discrepancy due to the subject becoming familiar with the machine, there are other factors that may have affected the data outcomes and can be considered limitations of this study. Such factors include: inter-tester inconsistencies, subject position set-up, and degree of stabilization offered to

subjects through restraints. Intertester inconsistencies were limited due to training sessions and written protocols provided for each tester. Nevertheless, human error can contribute to data collection in any study. Subject position set-up and degree of stabilization offered by restraints could be responsible for differences between the sessions. In respect to comparing the data presented in this study to other findings, caution must be taken to consider study designs and methods. This study focused specifically on the Kin-Com dynamometer at a speed of 60°/s for concentric isometric contractions. The peak torque values presented can be compared to data collected from other dynamometer machines or to studies using differing speeds or types of exercise if consideration is given to variations of study design and methodology used. Age, gender, and activity levels of the subjects should also be a consideration when analyzing data.¹⁷ In addition, the reader is cautioned about generalizing the results of this study due to the small size of the sample.

The AM/PM ratios and the results of the t-test for sampled pairs reinforce the conclusion that there is no significant difference in data collection related to the time of day subjects are tested. In other words, the data supports the null hypothesis that there is no significant difference in maximal quadriceps torque production in morning hours (AM) compared to maximal quadriceps torque production in afternoon hours (PM). Based on these facts, general strength assessments can be performed throughout the day to accurately measure and compare muscle torque production regardless of previous testing session times.

The exception to this finding is the theory of specificity. Previous studies have reported differing testing results in relation to the time of day training is performed.¹⁴

This study did not perform any sessions for the purpose of muscular training, therefore avoiding any variance due to training habits. The results of this study can be accurately applied only to subjects who have not participated in physical preparation coinciding with the time of day at which the evaluation is expected to be performed.

For accuracy of comparison, Pearson's Correlation statistics were also run. This type of data analysis was used in a study by Tredinnick and Duncan³ and can be safely compared to this research since several of the variables correspond. Some of the corresponding variables include: male subjects with no known lower extremity orthopedic problems, use of a Kin-Com dynamometer for testing, the use of one familiarization session followed by two data collection sessions, and the speed of 60°/s was used to test concentric isokinetic contractions. The main difference between the study by Tredinnick and Duncan³ and this study is the fact that the former compared data collected on the same day of the week at the same time of the day, while this study deliberately varied the testing between AM and PM sessions. Nevertheless, the results strongly coincide. Tredinnick and Duncan³, using same time of day sessions, found a correlation of .89 on the Kin-Com, while this study, using differing times of day, found a correlation of .90.

This high degree of reliability displayed by the dynamometer can be useful for clinicians who use strength testing for assessment and reassessment during treatment sessions. Based on these results, therapy session times of data collection do not need to concur for accurate portrayals of progress and the collection of objective, measurable data, provided the recommended protocol used in this study is followed. This protocol is recommended in order to minimize external variables such as stabilization, proper

alignment of the knee joint, proper warm-up, and machine parameters (concentric isometric contractions at 60°/s).

Recommendations for further studies include testing of the subjects at differing speeds, expanding the sample size to differing age groups and gender, use of different contraction types such as eccentric isokinetic contractions, and testing other joints and muscle groups of the body.

CHAPTER V

CONCLUSION

This study has found that peak torque measurements on a Kin-Com dynamometer for the concentric isometric contraction of the quadriceps muscle at 60°/s are independent of the time of day tested. The difference between mean peak torque values of AM versus PM testing sessions was 1.5 ft-lb and the correlation coefficient was .90.

The purpose of this study was to compare maximal quadriceps torque production in the AM to maximal quadriceps torque production in the PM. Based on the results of this study, clinical assessment of exercise performance or injury progression can be achieved without bias to the time of day the exercise was performed provided physical preparation or training was not performed to coincide with the time of day at which the evaluation is conducted. In addition, a consistent protocol for subject positioning and dynamometer parameters should be implemented. If the presented protocol is followed, strength assessment can be considered reliable and unaffected by human circadian rhythms.

The methods of this study can also be used to develop protocols that are specific to the varying clientele. Further research is encouraged.

APPENDIX A

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM FOR
NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED PROJECTS
INVOLVING HUMAN SUBJECTS

EXPEDITED REVIEW REQUESTED UNDER ITEM 3 (NUMBER[S]) OF HHS REGULATIONS
 EXEMPT REVIEW REQUESTED UNDER ITEM _____ (NUMBER[S]) OF HHS REGULATIONS

**UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM
 FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED
 PROJECTS INVOLVING HUMAN SUBJECTS**

PRINCIPAL

INVESTIGATOR: Shawn Doctor, Shawn McCoul, Michael Rexin, Denise Willardsen
 TELEPHONE: (701)-777-9485 DATE: 2/11/98
 ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: 3904 University Ave. #16,
Grand Forks, ND 5820

PROPOSED SCHOOL/COLLEGE: University of North Dakota DEPARTMENT: Physical Therapy
 PROJECT DATES: 3/1/98-12/18/98 PROJECT TITLE: A Comparison of the Maximal Torque Production of
 the Quadriceps Muscle During Morning and Afternoon Strength Assessment.

FUNDING AGENCIES (IF APPLICABLE): _____

TYPE OF PROJECT (Check ALL that apply):

NEW PROJECT CONTINUATION RENEWAL DISSERTATION OR THESIS RESEARCH STUDENT RESEARCH PROJECT
 CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Mark Romanick

PROPOSED PROJECT: INVOLVES NEW DRUGS (IND) INVOLVES NON-APPROVED USE OF DRUG INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):

MINORS (< 18 YEARS) PREGNANT WOMEN MENTALLY DISABLED FETUSES MENTALLY RETARDED
 PRISONERS ABORTUSES UND STUDENTS (> 18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE _____

IF YOUR PROJECT HAS BEEN WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME OF BOARD(S):

Status: Submitted; Date _____ Approved; Date _____ Pending

1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.)

The purpose of this study is to compare maximal quadriceps torque production in morning hours to maximal quadriceps torque production in afternoon hours.

Twenty-five to fifty male subjects will take part in this study. A maximum torque will be assessed with a Kin-Com isokinetic machine to compare the amount of quadriceps torque produced in early morning hours as compared to afternoon hours. Each subject will be randomly placed in one of two test groups. The first group will be initially tested in the morning. The second group will be initially tested in the afternoon. The groups will be re-tested in the opposing time slot after at least three days have passed. A comparison will then be made between quadriceps torque production in the morning and afternoon.

The significance of this study is to determine if the time of day affects maximal torque production of the quadriceps muscle. The results may be applied to clinical objective testing procedures and may help with development of the most efficient strengthening schedules.

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: Twenty-five to fifty male subjects between the ages of 19 and 45 will participate in this study. They will be randomly assigned into a morning (no longer than 1.5 hours after awakening from a 6 hour or longer sleep) training group and an afternoon (must be awake for longer than 8 hours but no more than 16 hours) training group. All subjects will complete a consent form in accordance with the University of North Dakota Human Subjects Review Committee. *Exclusion criteria* will consist of the following: 1) subjects who have had a history of neurological disorders or previous leg/knee trauma within the last year or have current knee dysfunction, 2) subjects who report any muscle fatigue or weakness due to activity prior to the testing time.

Instrumentation: The equipment used to perform the testing will consist of a Kin Com AP (Chattanooga Corp., Chattanooga, TN). The Kin Com AP is a commonly used exercise machine which is capable of measuring muscle strength through peak torque values. The warm up will be performed on a stationary bicycle provided by the Physical Therapy department.

Procedures: Before the testing begins, all of the subjects will experience a trial-run of quadriceps torque measure to familiarize the subject with the nature of the testing procedure. At this time, the parameters of the Kin-Com machine will be set and recorded for each individual.

On the first day of testing, the maximum torque production of each subject's right quadriceps muscle will be assessed to determine the strength level of each subject. The subject will begin by performing a two minute warm-up on a stationary bicycle. A preliminary warm-up set will be performed to re-familiarize the subject with the testing procedure. The subject will then complete a concentric knee extension (type of exercise in which the muscle shortens while the force is being exerted) test consisting of 6 repetitions at sixty degrees per second. The results of this test are recorded by a dynamometer and stored in the computer's data base.

The subjects will be re-tested at the opposite time of their initial test following the same procedure as previously stated.

3. BENEFITS: (Describe the benefits to the individual or society.)

The benefits of this study will determine if maximal torque production of the quadriceps muscle is affected by the time of testing. This may broadly be applied to strength assessment of other muscles. If significant variations do exist between time of day and torque production, then clinicians must take into account time of day when testing and re-testing. From this data, further studies may be conducted to compare training times for optimal strength gains and athletic performance.

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.)

Although any exercise poses certain minimal risks, our study is designed to further minimize these risks. Some precautionary measures include: 1) Instructions will be provided to the subject to terminate the procedure if at any time he is uncomfortable or experiences pain and will be provided a stop button ("kill switch") which will immediately stop the procedure. 2) A two minute warm up on a stationary bicycle will be performed to adequately prepare the muscles for activity. 3) A warm-up test set will be performed to further familiarize and prepare the subject for the test. 4) The Kin-Com machine is also equipped with electronic and mechanical stops to prevent movements outside of each subjects physiological range of motion (ROM). Although we have taken every measure to prevent risk, the remote possibility remains for a musculoskeletal injury, such as muscle strain.

- 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 enclosed consent form will be signed by each subject involved in this study. The forms will be kept in the University of North Dakota Physical Therapy department in locked filing cabinets. The only access to these cabinets will be to the examiners, the student advisor, Mark Romanick, and the head of the Physical Therapy department, Thomas Mohr, P.T. PH.D. The forms will be kept on file for a period of 3 years after the last day of experimental study involving the subjects. The data collected and stored on the Kin Com AP computer is kept behind locked doors in the Physical Therapy department.

- 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
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 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

STUDENT RESEARCHERS: As of June 4, 1997 (based on the recommendation of UND Legal Counsel) the University of North Dakota IRB is unable to approve your project unless the following "Student Consent to Release of Educational Record" is signed and included with your "Human Subjects Review Form."

STUDENT CONSENT TO RELEASE OF EDUCATIONAL RECORD¹

Pursuant to the Family Educational Rights and Privacy Act of 1974, I hereby consent to the Institutional Review Board's access to those portions of my educational record which involve research that I wish to conduct under the Board's auspices. I understand that the Board may need to review my study data based on a question from a participant or under a random audit. The study to which this release pertains is

A Comparison of the Maximal Torque Production of the Quadriceps Muscle During Morning and Afternoon Strength Assessment.

I understand that such information concerning my educational record will not be released except on the condition that the Institutional Review Board will not permit any other party to have access to such information without my written consent. I also understand that this policy will be explained to those persons requesting any educational information and that this release will be kept with the study documentation.

Date

Signature of Student Researcher

¹Consent required by 20 U.S.C. 1232g.

APPENDIX B
STATEMENT OF INFORMATION AND CONSENT

INFORMATION AND CONSENT FORM

TITLE: A Study on the Maximal Torque Production of the Quadriceps Muscle During Morning and Afternoon Strength Assessment

You are being invited to participate in a study conducted by Shawn Docktor, Shawn McCoul, Michael Rexin, and Denise Willardsen, physical therapy students and Mark Romanick, a physical therapy instructor at the University of North Dakota. The purpose of this study is to determine if the time of day affects maximal torque production of the quadriceps muscle, by comparing maximal torque production in the morning and in the afternoon.

You will be asked to exercise on the Kin Com AP machine on 3 occasions – one familiarization session, one morning session, and one afternoon session. The Kin Com AP is a commonly used exercise machine which is capable of measuring muscle strength through peak torque values. At these sessions, you will be asked to perform a 2 minute warm-up on a stationary bicycle before being tested. You will then be required to perform maximum effort knee extensions while a computer records the amount of torque produced.

The study will take approximately 15-30 minutes of your time per session. You will be asked to report to the Physical Therapy Department at the University of North Dakota at an assigned time. You will then be asked to change into gym shorts for the experiment. We will first record your age, height and weight. During the experiment, we will be recording the amount of maximal torque production for your quadriceps muscles.

Although the process of physical performance testing always involves some degree of risk, the investigators in this study feel that the risk of injury or discomfort is minimal. In order for us to record the muscle torque, we will require you to exert your maximal force during an isokinetic knee extension movement on three separate days. One session will be for training purposes and the other two sessions will be for data collection. The data collection sessions will require you to participate in one morning and one afternoon session. For these sessions, you will be asked to perform a two minute warm up on a stationary bicycle, followed by the testing procedure consisting of 6 maximal efforts of knee extension. The amount of exercise you will be asked to perform will be minimal.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only by the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his health. Your decision whether or not to participate will not prejudice your future relationship with the Physical

REFERENCES

1. O'Sullivan SB, Schmitz TJ. *Physical Rehabilitation: Assessment and Treatment*. 3rd ed. Philadelphia, Pa: FA Davis Co; 1994:95.
2. Hislop HJ, Montgomery J. *Daniels and Worthingham's Muscle Testing: Techniques of Manual Examination*. 6th ed. Philadelphia, Pa: WB Saunders Co; 1995:2-9.
3. Trendinnick TJ, Duncan PW. Reliability of measurements of concentric and eccentric isokinetic loading. *Phys Ther*. 1988;68:656-659.
4. Reilly T. Human circadian rhythms and exercise. *Crit Rev Biomed Eng*. 1990;18:165-180.
5. Prosser RA, Dean RR, Edgar DM, Heller HC, Miller JO. Serotonin and the mammalian circadian system: in vitro phase shifts by serotonergic agonists and antagonists. *J Biol Rhythms*. 1993;8:1-16.
6. Thomas CL, Vardara DR, Egan EJ, Willert BA. *Taber's Cyclopedic Medical Dictionary*. 17th ed. Philadelphia, Pa: FA Davis Co; 1989:457.
7. Ganong WF. *Review of Medical Physiology*. 17th ed. Norwalk, CT: Appleton & Lange, 1995:342-344.
8. Trine MR, Morgan WP. Influence of time of day on psychological responses to exercise: a review. *Sports Med*. 1995;20:328-337.
9. Bernhard T, Giacomoni M, Gavarry O, Seymat M, Falgairette G. Time of day effects in maximal anaerobic leg exercise. *Eur J Appl Physiol*. 1998;77:133-138.
10. Marriott JD, Hartley LH, Sherwood J. Lack of heart rate variation between morning and afternoon exercise testing in coronary artery disease patients. *J Applied Physiol*. 1993;74:1012-1015.
11. Galliven EA, Singh A, Michelson D, Bina S, Gold PW, Deuster PA. Hormonal and metabolic responses to exercise across time of day and menstrual cycle phase. *J Appl Physiol*. 1997;83:1822-1831.

12. Reilly T, Garrett R. Effects of time of day on self-paced performances of prolonged exercise. *J Sports Med Phys Fitness*. 1995;35:99-102.
13. Reilly T, Baxter C. Influence of time of day on reactions to cycling at a fixed high intensity. *Br J Sports Med*. 1983;17:128-130.
14. Hill DW, Cureton KJ, Collins MA. Circadian specificity in exercise training. *Ergonomics*. 1989;32:79-92.
15. Norkin CC, Levangie PK. *Joint Structure and Function: A Comprehensive Analysis*. 2nd ed. Philadelphia, Pa: FA Davis Co; 1992:35-36,40,107-111.
16. Snow CJ, Blaklin K. Reliability of knee flexor peak torque measurements from a standardized test protocol on a Kin/Com dynamometer. *Arch Phys Med Rehabil*. 1992;73:15-21.
17. Ho D. *Concentric and Eccentric Isokinetic Normative Ratio Values of the Quadriceps Muscle in Asymptomatic Knee Subjects*. Grand Forks, ND: University of North Dakota; 1996. Thesis.
18. Hislop HJ, Perrine JJ. The isokinetic concept of exercise. *Phys Ther*. 1967;47:114-117.
19. Farrell M, Richards JG. Analysis of the reliability and validity of the kinetic communicator exercise device. *Med Sci Sports Exerc*. 1986;18:44-49.
20. Reitz C, Rowinski M, Davies G. Comparison of Cybex II and Kin/Com reliability on the torque measures of peak torque, work, and power at three speeds. *Phys Ther*. 1988;68:782.
21. Kues JM, Rothstein JM, Laumb RL. Obtaining reliable measurements of knee extensor torque produced during voluntary contractions: an experienced investigation. *Phys Ther*. 1992; 72:497-501.