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

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

by

Michael Rexin
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 Michael Ray Rexin 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 Mike Rep

Date December 10, 1998
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Acknowledgements

There have been numerous people in my life that have helped me to get this far in Physical Therapy School. I would especially like to thank the people who have directly helped me with my studies including the faculty here at the University of North Dakota, my classmates, and to all my friends who have studied long hours and put in lots of time preparing, asking questions, and practicing for exams. I would also like to thank my parents most of all for all their support they have given me throughout my life. Without their motivating talks, the constant moral support, and without them just being there whenever I needed them, all of this would not have been possible.
Abstract

The purpose of this study is to compare maximal quadriceps peak torque production in isokinetic strength assessment in the morning and the afternoon. Thirty male subjects between the ages of 21 and 43 volunteered for this study. The subjects were randomly assigned to either an early morning group (7:30 AM to 9 AM) or an afternoon group (2:30 PM to 5 PM). Each subject performed six maximal concentric isokinetic contractions with the quadriceps muscles after a warm up and an initial familiarization session. Data analysis was done using a t-test for paired samples and Pearson’s correlation. The results showed a .90 correlation coefficient and t(29) = -46, p<.05 showing that there was no significant difference between the AM and PM testing times. In conclusion, the use of the Kin-Com dynamometer in strength testing of peak torque in the quadriceps muscles is going to be accurate regardless of the time of day when comparing morning and afternoon strength testing.
Chapter I

Introduction

Everyone who has ever participated in any activity whether it is in sports, rehabilitation, jobs, or school has more than likely felt like some times of days are better than other times of day. It may be the hour after lunch, the morning, the evening, or the afternoon when the person feels the most energized, most awake, and maybe the strongest. They may have even asked themselves if there is a time of day that is optimal for activities such as strengthening and exercise. This question is certainly worth asking when patients in the process of rehabilitation or subjects in strengthening programs are considered. It would be important for clinicians to know if there is a difference in assessment of strength with respect to time of day when considering patient’s rehabilitation time, safety, and progression.

This study examines a common assessment and strengthening tool, the isokinetic dynamometer, and the effects of time of day on strength testing. The purpose of this study is to compare maximal quadriceps peak torque production in isokinetic strength assessment in the morning and afternoon. Any significant difference in strength could be very important when considering rehabilitation time and when determining return to prior activity level. For instance, Shelbourne and Wilcken’s protocol requires patients to achieve 70% of normal strength by the 5th week of rehabilitation for progression into the next phase of rehabilitation. If this is not met only due to testing error, the patient could
be faced with an extra two to three weeks of physical therapy at an unneeded expense in cost. If the patient scores over the 70% because of testing error, the patient may return to their prior level of function too quickly and could be at higher risk for reinjury. It also has been shown that too rapid a progression in a rehabilitation program can cause muscular injury and joint reinjury. Thus, it is important for clinicians to be confident in the testing procedure and to make sure it is accurate no matter what time of day the testing occurs.

The null hypothesis of this study states there is no significant difference in peak torque of the quadriceps muscle in isokinetic strength testing when performed in the morning versus the afternoon. If this hypothesis holds true, there would be no need for clinicians to monitor times of testing of muscle strength. The alternate hypothesis is just the opposite and states that there is a significant difference in the peak torque of the quadriceps muscle between the morning and the afternoon in isokinetic strength assessment. The alternate hypothesis could give clinicians reason to schedule patients more strategically when considering strength testing to allow for more accurate results.

As this paper continues, there will be numerous referrals to the word circadian rhythms. Circadian rhythms can be defined as 24-hour regularly repetitive physiological rhythms, found in humans, animals, and plants. The presence of circadian rhythms has been reported and presented in conferences of the Society for Biological Rhythms as far back as 1937 in Ronneby, Germany and has been well known to exist for many years.
Much research has been done to associate various physiologic processes to this sinusoidal rhythm found in humans. Circadian rhythms have been found in the endocrine system, cardiovascular systems, and in body temperature.\textsuperscript{4}

In the endocrine system, researchers on circadian rhythms have focused on adrenocorticoptric hormone (ACTH), a pituitary hormone involved in stimulating the adrenal glands to release adrenal corticosteroids. ACTH concentrations are found to be higher in the morning than the evening.\textsuperscript{4,5} It has been shown by researchers this rhythm is not simply due to habit, posture, or some other cause while some other endocrine functions under investigation have not shown this true circadian rhythm. The function of the increase in release of ACTH eventually involves body processes that metabolize fats, carbohydrates, and proteins.\textsuperscript{6}

In the cardiovascular system, blood pressure, pulse rate, plasma volume and cardiac output have all been shown to follow a circadian rhythm.\textsuperscript{4} Peak curves of blood pressure have been found around 12 noon and 6 PM with a low in blood pressure found at 3 AM.\textsuperscript{7} Response of the cardiovascular system to exercise training has shown better results in adaptive response of the heart rate in subjects exercising in the afternoon (3 to 3:30 PM) compared to subjects in the morning (9 to 9:30 AM) and evening (8 to 8:30 PM).\textsuperscript{8}

Body temperature has been investigated by numerous researchers to determine the presence of circadian rhythms.\textsuperscript{3,4,9,10} Freivalds et al\textsuperscript{3} showed a steady rise in deep body temperature during the day with a peak around 9 AM and the low temperature found at 4 AM. In another study, Stolz et al\textsuperscript{9} reported a highly significant 24-hour circadian rhythm in oral temperature.
Many studies on the above systems within the human body have been performed for many years. More recently there are beginning to be more attempts to associate peak strength with peaks in the other physiologic processes that are known to follow a circadian rhythm. Even though this study will not be able to determine circadian rhythms it will be important to recognize their possibility and consider other researchers’ results on this matter.

This study focused on peak torque measurements when analyzing data for the strength assessment of the quadriceps muscles. This study should help determine if there can be a significant difference in strength in isokinetic strength testing during times of day consistent with times of day in the clinical setting.

The questions this study will hope to answer include:

1. Is there any significant difference in peak torque in isokinetic strength assessment of the quadriceps muscles at different times of day?

2. Can the Kin-Com be considered to be reliable in strength assessment without being time of day dependent?
Chapter II

Literature Review

There are numerous studies in the literature on effects of time of day on strength and on other physiologic process in the body. This study focuses on testing of strength with isokinetic strength assessment during hours which may be applied to the clinical setting. The following studies have many differences but also have some similarities and they all are related to time of day and strength components which form the basis for this study.

Coldwells et al. tested the reliability of a portable dynamometer in isometric strength assessment at different times of day. They tested both back extension and leg extension strength in 4 male subjects. The testing times they used were at 4 hour intervals running from 2 AM to 10 PM. Each subject was tested within a 48-hour time period and was not tested within 8 hours of a previous test. The examiners found a time of day effect was evident in both back extension and leg extension strength tests. Peak of leg extension strength was found to be at 6:20 PM and the peak of back extension strength was found to be at 4:53 PM. A peak to trough variation was found to be 21.1% of the mean in back extension strength and 17.9% of the mean in leg extension strength.

In a study on three subjects by Frievald, it was found that elbow flexor strength exhibited signs of following a significant circadian rhythm. The data of the elbow flexor strength was also correlated with changes in deep body temperature. This study explains
that a correlation exists between deep body temperature and strength; therefore peak strength appears to be dependent on circadian rhythms similar to other physiologic processes in the human body.

These two studies both have a very small sample size of four and three subjects respectively. The small sample size makes it difficult to be able to make any substantial claims about strength following circadian rhythms.

In another study headed by Atkinson, a peak in leg strength was found in the early evening. This study involved 20 participants ranging in age from 18 to 30 who had their isokinetic leg strength tested at 1.57rad/s (90°/s). These subjects also had their isometric leg strength tested. From this testing, Atkinson recognized a “post-lunch dip” in strength in the early afternoon. Post-lunch may not be a representative term for this dip in performance because it was found to be independent of participant’s consumption of food. However this “dip” is termed, it does have some significance as to the possibility of more differences in strength testing due to time of day. Data from the isometric testing showed peak times occurred in the late morning and again in the late afternoon. There have also been other studies agreeing with this performance dip in the early afternoon. By basically demonstrating the possibility of two peaks in one time of day there may be more than one optimal time of day to assess patient’s strength.

In 1996, Atkinson and Reilly teamed up to do a comprehensive review on circadian variations in sports performance. Within the review, a special section was described about the effects of circadian rhythms on strength. They consistently found peaks in isometric strength in the late afternoon or in evening hours. The studies
reviewed consisted of strength testing for grip strength, elbow flexion, leg strength, and back strength. Atkinson and Reilly also reported there was a significant difference in strength at different times of day using isokinetic testing in speeds less than six rad/s (340°/s). The variations in times of peak strength ranged from 2 PM to 7 PM for grip strength and approximately 10 PM for peak torque values for isokinetic leg extension.

In the most closely related study to this study, Wyse et al. found the greatest peak extension torque values with isokinetic testing of the quadriceps muscles (1.05 rad/s) are found between the hours of 6 PM and 7:30 PM. This study tested nine adult collegiate males at 3 different times during the day on 3 different days which were separated by greater than 7 days between sessions. The first session was from 8 AM to 9 AM, the second time was 1 PM to 2 PM and the third session was between 6 PM and 7:30 PM. Because of the significance found in variability between time of day and maximal strength tests, they recommended to only test strength within 30 minutes of the previous testing time.

Although this study probably is the most closely related to our study and has possible implications, it continues to have some limitations. Once again with this study, the sample size is very small with only nine subjects participating. This number is far below the recommended level of 30 needed to decrease any significant chance of testing error. Also, many of the studies have results showing significant increases in assessment of peak torque values in the late evening at which times most clinics and health care
facilities are closed. If significance in strength changes are going to be found due to time of day, it would be most important to test during times which would be representative of times of day testing would occur in the clinical setting.

Other research has been done involving the effects of time of day on other activities and physiologic processes. Some examples of other studies look into the effect of time of day on sports, body temperature, industrial work, joint stiffness, nerve conduction velocity, and aerobic exercise to name a few.

When looking at sports, it has been shown swimming performance is best in the evening (10 PM) when compared to the afternoon and morning, with the morning being the time of worst performance. Swimming involves both strength and endurance, and it is believed that the performance of swimmers closely follows the rise of temperature of the body during the course of the day. It is of interest, however, that the same study on swimming did not produce any significant difference in grip strength due to time of day. It is not clear if the relationship with internal body temperature is entirely correlative either. The peak temperature in the body was found to occur at about 8 PM and did not equal the time (10 PM) of peak performance in swimming.

In summary of this review of the literature, there continues to be variability in the research regarding optimum time of day for strength assessment. The limited research on this topic makes it difficult to satisfactorily determine the significance of time of day on strength testing. There are large discrepancies on effects of time of day on grip strength and there are also discrepancies on what time is most significant for highest values of
strength during strength assessment for the different muscles involved. Because of the limited number of repeated studies, it is too difficult to determine if there is a consistent time of day for maximal strength. There is even a possibility of time of day for maximal strength being specific to the muscles or activity being tested. However, the literature does seem to be fairly consistent in reporting of greater strength found in the later hours of the day compared to the early morning hours.\textsuperscript{3,10,13} With our study we will try to determine if there is significance in time of day in strength assessment of the quadriceps muscle peak torque during a period of the day which is appropriate to hours used in the clinical setting. The use of a single trial isokinetic strength test will also be more accurate to following testing protocols within today's physical therapy clinic.
Chapter III

Methods

Thirty healthy male subjects, between the ages of 21 and 43 volunteered to participate in this study. Fitness levels of the subjects were quite variable, consisting of subjects who participated in intervarsity sports to subjects with limited recreational activity. All subjects were currently enrolled as students of the University of North Dakota in Grand Forks, North Dakota. To participate in this study each subject agreed to not participate in any lower extremity strengthening or aerobic exercise and activities for one day prior to each testing procedure. Volunteers excluded from this study included subjects with any neurological disorders and/or any leg or knee pathology within the last year. Also, subjects were excluded if they had any current knee dysfunction or muscle soreness/fatigue prior to the testing procedure. The subjects were randomly assigned to either an early morning (no longer than 1.5 hours after awakening from a 6 hour or longer sleep) test group or an afternoon (must have been awake for longer than 8 hours but less than 16 hours) test group. The AM and PM testing session were completed between 7:30 to 9:30 AM and 2:30 to 5 PM respectively. Participants were informed of the testing procedures and took part in a familiarization session with the researchers and equipment.
The volunteers were informed of their rights as a participant in accordance with the Institutional Review Board procedures at the University of North Dakota. Each subject signed an informed consent form prior to voluntary participation in the study (see appendix B).

Instrumentation

The Kin-Com (model 125AP with software version 4.06, Chattecx Corp., Chattanooga, TN) dynamometer was used to evaluate peak torque values in this study. A dynamometer is a hydraulically driven, microcomputer-controlled device designed to measure torque and work during eccentric and concentric isokinetic loading. 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 perpendicular distance that force lies from the axis of rotation. In relation to the dynamometer, torque is the product of the muscle force measured at the resistance pad multiplied by the pad’s perpendicular 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. 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. Peak torque is the highest torque produced at one point in the range of motion. 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.\textsuperscript{16}

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.\textsuperscript{16} The two types of isokinetic contractions assessed by the dynamometer, eccentric and concentric, are differentiated by the muscle action. In both types of contractions, 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 muscle will lengthen as it contracts.\textsuperscript{16}

The reliability and validity of the Kin-Com to assess isokinetic torque during successive sessions has been established in several previous studies. Snow and Blacklin\textsuperscript{17} 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 represent a higher reliability for slower speeds. In an analysis of the reliability and validity of the kinetic communicator exercise device by Farrell and Richards,\textsuperscript{20} 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. In addition, they found lever arm speed to be within 1.5% of the target speed and no discrepancy noted in position measurement. A study by Reitz et al\textsuperscript{21} 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 Duncan\textsuperscript{15} resulted in an interclass correlation coefficient for intertest reliability of concentric torque at 60°/s to be .89 and a coefficient of .85 for concentric work.

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.\textsuperscript{22} 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.\textsuperscript{22} 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.\textsuperscript{15} This data has also been reinforced by Snow and Blaklin\textsuperscript{6} 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.
Procedure

Four examiners administered the testing, with at least two present at each session. 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. It has been shown reliable measurements can be achieved by multiple examiners with variable isokinetic testing experience.23

Each subject was first oriented to the Kin-Com machine in a familiarization session one week prior to the actual testing procedure. Before being positioned on the Kin-Com, each subject warmed up on a Monark stationary bike for a period of 2 minutes. Each subject’s name, weight, and age were then recorded. Each subject was positioned on the Kin-Com to fit his specific physical dimensions. The subject’s settings were saved during the familiarization session on the computer to ensure the exact position could be recalled for further testing procedures. Position settings for each subject were also established and recorded at this time following the protocol of the Kin-Com Basic Training Course Workbook.24 Each subject was tested in a seated position with two restraining belts around the trunk and one restraining belt around the waist. Each subject’s right knee rotational axis was aligned with the dynamometer’s axis of rotation using the femoral epicondyles as the center. The subject’s right lower leg was then secured to the dynamometer arm with a double shin pad and the right thigh was stabilized with a restraining pad. At this time, the subject was instructed to perform six submaximal concentric contractions of the quadriceps and to relax all musculature on the return of the dynamometer arm to the flexed position after each repetition. After a rest period of 2 minutes, the subject performed six maximal repetitions of knee extension.
Concentric isokinetic testing was performed at 60°/s to test the maximal quadriceps torque between the ROM of 10° and 80° of knee flexion. At this time in the familiarization session, the subject was asked if he was comfortable with the Kin-Com machine and the testing process. The set of six repetitions was repeated if the subject was uncomfortable with the process. If the subject felt comfortable, the session ended. He was then scheduled for a testing time no less than 3 days from the familiarization session.

All subjects were randomly assigned to 1 of 2 groups with 15 subjects in each group. The first group was initially tested in the early morning. The second group was initially tested in the afternoon. The groups were then retested in the opposing time slot following a minimum of 3 days between tests. The testing procedure followed the same format as the familiarization session with a warm up on the stationary bike, a submaximal set of six concentric knee extensions, and the recorded maximal set of six contractions.

Data Analysis

Data analysis was completed using the SPSS 7.5 for Windows program. 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 IV

Results

As mentioned in Chapter III, 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.

Table 1. – Mean Maximal Peak Torque Values for the Entire Sample and Two Separate Groups

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mean (ft-lb)</th>
<th>Standard Deviation</th>
<th>Range (ft-lb)</th>
<th>AM PM Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AM</td>
<td>PM</td>
<td>AM</td>
<td>PM</td>
</tr>
<tr>
<td>Entire Sample (n=30)</td>
<td>185.1</td>
<td>186.6</td>
<td>35.6</td>
<td>41.1</td>
</tr>
<tr>
<td>Group I (n=15)</td>
<td>184.6</td>
<td>181.6</td>
<td>31.3</td>
<td>38.9</td>
</tr>
<tr>
<td>Group II (n=15)</td>
<td>185.7</td>
<td>191.7</td>
<td>40.6</td>
<td>43.9</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Sample</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire Sample (n=30)</td>
<td>-0.46</td>
</tr>
<tr>
<td>Group I (n=15)</td>
<td>+0.52</td>
</tr>
<tr>
<td>Group II (n=15)</td>
<td>-2.14</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Sample</th>
<th>Correlation Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire Sample (n=30)</td>
<td>0.90</td>
</tr>
<tr>
<td>Group I (n=15)</td>
<td>0.82</td>
</tr>
<tr>
<td>Group II (n=15)</td>
<td>0.97</td>
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</tbody>
</table>
Chapter V

Discussion

With this study an attempt was made to obtain results that were more representative of what could happen in the clinical setting by staying within times of 7 AM and 6 PM. Also, by decreasing the number of limiting factors in the study and by not trying to control the subjects outside activity, it was possible to produce results that could be seen in a clinical setting where there is not a lot of control on the patient population. The high number of subjects was also important in this study as other studies have used a very low number of subjects that may have not been representative of the population.

The results obtained were in line with many other studies. The times being compared between morning and afternoon in strength assessment showed no significant difference in peak torque values as did the Wyse et al\textsuperscript{13} study on isokinetic leg strength. Their study did however find a significant difference between times of 8 to 9 AM and 6 to 7:30 PM. If significance was found between strength testing in different times of day, the results usually showed significant strength increases at 6 PM or later in the evening.\textsuperscript{3,9,11,12,13} As would be expected with a study not extending into the evening hours with strength assessment trials, this study did not show any significant difference in results.

When looking into the results of the Pearson’s correlation, this study compares very well with another study done by Tredinnick and Duncan.\textsuperscript{15} Their study was very
comparable to this study with testing of quadriceps peak torque at 60°/s with a Kin-Com dynamometer. This study was performed to determine whether there was any significant difference between the AM and PM while the Tredinnick and Duncan study was performed at the same time of day and the same day of the week. The results of the two studies are very comparable. A correlation of .89 for the Tredinnick and Duncan study was found and a .90 correlation was found for this study. Thus, this study also supports the null hypothesis which stated there is no significant difference between the AM and the PM in isokinetic strength assessment at 60°/s of the peak torque of the quadriceps muscles.

It seems to be that the key word in saying there is no significant difference in strength testing between the morning and afternoon is the word “afternoon”. The strength testing of our subjects ranged in the afternoon hours from 2:30-5 PM and no other study in our review of literature found any significant difference with any type of strength testing of any type of muscle if it was in the afternoon. From the data currently available, no matter if it is quadriceps peak torque or grip strength, it would appear the only significant difference in testing is going to be found in the evening hours. These evening hours usually extend beyond the time of most clinicians’ hours and should not cause any concern for variability to exist if patients or athletes are tested for strength between 7 AM to 6 PM.

This study is limited in how far we can go into the discussion of the possibility of a circadian rhythm existing in the subjects quadriceps muscle strength. The presence of circadian rhythms cannot either be denied or supported by this study. More trials than the two testing times would be needed to perform a more thorough test if a true 24-hour
circadian rhythm was to be detected. A representative curve can not be drawn with only two points of the curve known.

Limitations of the study may be due to a number of different factors. Probably the largest factor causing the study to be limited in accuracy may be because of human error. With any experimental trial with multiple testers there is bound to be small differences in set-up and instruction that could result in differing results. There is also no way to identify errors caused by having different combinations of testers as no record was kept in this study of which testers were present for each subject's trials. Another factor could be the large variation of activity level of the subjects as previous studies have shown higher circadian rhythm amplitudes in fit subjects compared to unfit individuals.

Recommendations for future studies include following patients in the middle of a rehabilitation program and determining if circadian rhythms or time of day differences exist in the strength of patients seen in the clinic. The study can also be improved by testing other parameters such as endurance, body temperature, or cognitive ability and correlating these factors with variations in strength. More trials of testing may also be needed to help support the reliability of the study when comparing the results of testing at different times of day and more trials could be performed at different isokinetic speeds on the Kin-Com dynamometer.

Conclusion

The purpose of this study was to determine if there was any significant difference in quadriceps peak torque with isokinetic strength assessment at 60°/s with testing in the AM compared to testing in the PM. This study found no significant difference between
time of day in morning and afternoon isokinetic strength assessment of the quadriceps muscle. Pearson's correlation values show a .90 correlation for the entire sample when comparing strength in the two different time slots of 7 AM to 9:30 AM and 2:30 PM to 5 PM. The results of this study do concur with many other studies in the literature.

It is important for clinicians in all fields of medicine to be certain of the precision of their evaluations and assessments of patients. This accuracy in assessment provides for the basis of their patient's treatment, treatment protocol, and even the eventual outcome. Physicians, physical therapists, athletic trainers, and occupational therapists all rely heavily on the results of muscle strength assessment, and it is important for their results to be accurate no matter how the testing procedure is performed and no matter when it is performed.

This study gives results that may indicate that the use of the Kin-Com dynamometer in strength testing of peak torque in the quadriceps muscles is going to be accurate and will not be significantly different regardless of the time of day, morning or afternoon, when the testing takes place. If clinicians are testing outside of 7 AM and 5 PM further research will have to be done to conclude that the accuracy of the quadriceps muscle testing will be the same throughout these time periods.
APPENDIX A

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

Project Director or Student Adviser

Training or Center Grant Director

_____________________
Date

_____________________
Date

_____________________
Date

(Revised 3/1996)
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 RECORD

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

1 Consent 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
Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigator involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Mark Romanick at (701)-777-2831. A copy of this consent form is available to all participants in the study.

In the event that this research activity (which will be conducted at the University of North Dakota in the Physical Therapy Department) results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payment, if any.

ALL OF MY QUESTIONS 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 RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this study explained to me by Shawn Dockter, Shawn McCoul, Michael Rexin, Denise Willardsen or Mark Romanick.

Participant's Signature Date

Witness (not the scientist) Date
References


