The Effect of Interset Rest Period Length on Quadriceps Muscle Recovery in Strength Training

Jesse J. Wosick
University of North Dakota

Follow this and additional works at: https://commons.und.edu/pt-grad

Part of the Physical Therapy Commons

Recommended Citation

https://commons.und.edu/pt-grad/487

This Scholarly Project is brought to you for free and open access by the Department of Physical Therapy at UND Scholarly Commons. It has been accepted for inclusion in Physical Therapy Scholarly Projects by an authorized administrator of UND Scholarly Commons. For more information, please contact zeinebyousif@library.und.edu.
THE EFFECT OF INTERSET REST PERIOD LENGTH ON QUADRICEPS MUSCLE RECOVERY IN STRENGTH TRAINING

by

Jesse J. Wosick
Bachelor of Science in Physical Therapy
University of North Dakota, 1996

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
1997
This Independent Study, submitted by Jesse J. Wosick 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 The Effect of Inter Set Rest Period Length on Quadriceps Muscle Recovery in Strength Training

Department Physical Therapy

Degree Master of Physical Therapy

In presenting this Independent Study Report in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the Department of Physical Therapy shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my work or, in his/her absence, by the Chairperson of the department. It is understood that any copying or publication or other use of this independent study of part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and the University of North Dakota in any scholarly use which may be made of any material in my Independent Study Report.

Signature

Date 1/3/97
# TABLE OF CONTENTS

List of Figures ............................................................................................................... v
List of Tables .................................................................................................................. vi
Acknowledgments ......................................................................................................... vii
Abstract ......................................................................................................................... viii
Introduction/Literature Review ...................................................................................... 1
Methods .......................................................................................................................... 12
Results ............................................................................................................................ 15
Discussion ......................................................................................................................... 23
Conclusion ......................................................................................................................... 27
Appendices ....................................................................................................................... 28
References ......................................................................................................................... 36
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Figure 1. Participants’ Peak Torque in Trial 1</td>
<td>16</td>
</tr>
<tr>
<td>2.</td>
<td>Figure 2. Mean Peak Torque of Trial 1 per Group</td>
<td>17</td>
</tr>
<tr>
<td>3.</td>
<td>Figure 3. Participants’ Peak Torque in Trial 2</td>
<td>18</td>
</tr>
<tr>
<td>4.</td>
<td>Figure 4. Mean Peak Torque of Trial 2 per Group</td>
<td>19</td>
</tr>
<tr>
<td>5.</td>
<td>Figure 5. Participants’ Mean Percent Recovery</td>
<td>20</td>
</tr>
<tr>
<td>6.</td>
<td>Figure 6. Mean Percent Recovery per Group</td>
<td>21</td>
</tr>
<tr>
<td>7.</td>
<td>Figure 7. Mean Percent Recovery per Gender</td>
<td>22</td>
</tr>
<tr>
<td>8.</td>
<td>Figure 8. Mean Percent Recovery per Dominance</td>
<td>25</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Table 1. Replenishment of Phosphagen Stores</td>
<td>9</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

I would like to express my appreciation to Mark Romanick MPT, LATC for his guidance, assistance, and encouragement with this independent study. I would also like to thank Jeff Barta LATC, CSCS at HealthSouth for his assistance and direction in finding appropriate literature. The University of North Dakota School of Medicine Department of Physical Therapy faculty and staff for their wisdom and knowledge. Finally, I would like to extend my deepest appreciation to my family and friends for their faith, support, and confidence in me.
ABSTRACT

Lower extremity strength training is one of the skills performed by physical therapists. The purpose of this experiment was to measure the percent of recovery of the quadriceps muscles after specified interset rest period lengths to obtain the optimal interset rest period length between sets in strength training.

Twelve male and twelve female healthy subjects were divided into three equal groups of eight (four males, four females). The subjects performed two sets of six repetitions of unilateral isokinetic knee extension with their dominant lower extremity on the Chattanooga KIN-COM Dynamometer. One, two, or three minute interset rest period lengths were used between sets, depending on group assignment.

Percent of recovery was obtained by dividing the peak torque of trial 2 by the peak torque of trial 1. Results, analyzed using a one-way ANOVA, showed no significant differences among the three groups of interset rest period lengths. Results also showed no significant differences in the percent of recovery between gender in the three groups. Therefore, this study concludes that interset rest period lengths of 1 minute are adequate for recovery of the quadriceps muscles in strength training for both males and females.
CHAPTER I
INTRODUCTION

The length of rest periods between sets is a key component in achieving optimal results in strength training. There is an enormous amount of literature on strength training, but there is very little research done on this specific topic. In order to understand how rest period length plays such a dramatic role, one must have adequate knowledge of strength training and its component parts: types of strength training, training principles, determinants of strength, training variables, fatigue and its contributing factors, and bioenergetics or energy sources.

Strength training or resistance training dates back 4500 years to the early Egyptians and Greeks who performed overhead lifts with heavy bags and lifted a calf every day until it reached full growth.\textsuperscript{1,2} Strength training has grown in popularity enormously over the past decade. DeNubile\textsuperscript{1} documented that it had been used initially by athletes to improve their strength and size and to develop and improve their physique. Recently, the role of strength training has expanded to use in a wide variety of situations including injury rehabilitation and prevention, weight control, osteoporosis prevention and treatment, heart disease prevention, colon cancer prevention, diabetes prevention, and physique and posture improvement.\textsuperscript{1,3}

Lillegard et al\textsuperscript{4} described strength training as "the use of progressive resistance methods to increase one's ability to exert or resist force." This involves the body's musculature to move against an opposing force, usually produced by some type of machine or equipment.\textsuperscript{5} There are three methods used in strength or resistance training. They are isotonic training, isometric training, and isokinetic training.\textsuperscript{1,5,6,7,8,9} Isotonic training is defined as strength training in which muscular contraction occurs with the same
force throughout the range of motion. It includes both concentric contractions and eccentric contractions. Popular types of isotonic strength training are free weight lifting with dumbbells and barbells, fixed resistance cable and pulley machines, constant and variable resistance machines, and elastic, hydraulic, or robotic resistance devices. Isometric strength training involves muscular contractions at a static or constant length. This involves exerting a near maximal voluntary contraction with minimal lengthening or shortening against an immovable, fixed object or resistance usually for 6 to 10 seconds. It is performed at a single joint angle, but has a carry over of strength increases at ± 20 degrees in either direction of the angle at which the exercise occurred. Isokinetic training is strength training which involves a type of isotonic contraction in which the muscle shortens against a resistance which allows the muscle to shorten at a preset speed. This involves the use of isokinetic machines such as the KIN-COM, BIODEX, and CYBEX machines.

There are two important principles involved in strength training. They are specificity of exercise and the overload principle. Specificity of exercise is employing an exercise which comes the closest to the functional activity for which one is trying to increase or improve performance. In other words, the more similar the training activity is to the desired movement or function, the more likely the positive carryover. Specificity of exercise is also stated as the “SAID” principle which stands for Specific Adaptation to Imposed Demands. Baechle explained that this means that “the type of demand placed on the body controls the type of adaptation that takes place.” The overload principle states that a muscle will grow larger and stronger only when it performs tasks above that which it has previously performed. This means providing a greater stress or load on the body than that to which it is normally accustomed will lead to increased muscle strength.

There are a variety of determinants or factors responsible for how much strength an individual is capable of producing. This includes muscle size, body size, muscle
tendon lever arrangements, fiber type, neural factors, and psychological factors. Muscle size is determined by the cross-sectional area of the involved muscle or muscles. Generally, skeletal muscle can produce 3 to 4 kg of force/cm² in both males and females. Therefore, this concludes that the greater the cross-sectional (muscle size), the greater the expected strength output.

Body size or mass has a positive correlation with strength output, but this is not necessarily true when considering the correlation between body size and the strength to mass ratio. Therefore, larger athletes may have greater total strength output, but smaller athletes may have a higher strength to mass ratio. This also becomes very evident with the differences between gender and strength. Men are generally stronger than women and produce 50% greater strength output in the upper extremities and 30% greater strength output in the lower extremities. This is not true when strength to mass ratio is considered. There are very few qualitative differences in strength between the genders in this respect.

Muscle tendon lever arrangement is a genetically passed trait that helps determine strength. Some are genetically gifted with lever arrangements that favor strength. Lever arrangement also refers to the class of lever whether it be first class in which the fulcrum is between the resistance and the force (triceps brachii), second class in which the resistance is between the fulcrum and force (none really reported in body except possibly jaw opening against a resistance), or third class in which the force is between the fulcrum and the resistance (biceps brachii). The origin and insertion also plays a part in the lever systems of the body. They help determine the speed of the desired movement. A spurt muscle is one which originates a distance from the involved joint and inserts near it (biceps brachii). A shunt muscle is one which originates near the involved joint and inserts far from it (brachioradialis). Movement occurs at a quicker rate in spurt arrangements.

Muscle fibers are the long, cylindrical, multinucleated cells arranged in a parallel fashion that make up the contractile portion of muscle. They appear in the early stages of development and are determined by genetics. There are two distinct types of fibers, Type
Type I (red or slow twitch) and Type II (white or fast twitch). Type I fibers are primarily used for aerobic types of activity because they have a slow speed of contraction (100 to 120 milliseconds) and low glycolytic capacity. Type II fibers are the fibers primarily utilized in anaerobic activity such as strength training. This is because they have a faster rate of contraction (40 milliseconds) and strong glycolytic capacity. Type II fibers have been further subclassified into IIa, IIb, and IIc. Type IIa have been termed “intermediate fibers” because they are fast contracting but have equal aerobic and anaerobic metabolisms. Type IIb are the fibers that possess the greatest anaerobic potential and are the ones most commonly utilized in short-term activity such as strength training. Type IIc fibers are undifferentiated. Athletes with a predominance of Type II fibers, especially Type IIb, generally have a predominance to excel in strength training.

Neural factors tend to go hand in hand with fiber type in determining strength. Type I fibers contain a small, lightly myelinated, small membrane surfaced motoneuron; whereas, Type II fibers have a large, heavily myelinated, large membrane surfaced motoneuron. For this reason Type II fibers are called upon more quickly and, therefore, are used in short term anaerobic activity. Training can enhance neural mechanisms by improving recruitment patterns and efficiency. These neural mechanisms can also lead to increased gains in strength in a short period of time, primarily the result of neural learning.

Psychological factors also play a large part in determining strength. This involves the power of positive thinking and mental imaging. Positive thinking involves self-statements such as “I will do it” or “I can do it.” Mental imaging is the process of mentally picturing the completion and the achieving of an activity. Both have been shown to enhance performance. The opposite can also occur. By thinking negatively, inhibition can occur and decrease performance/results. The athlete must learn that the mind plays an important role in enhancing performance.

Strength training programs contain 6 training variables that are manipulated to achieve desired results. The variables are: choice of exercises, order of exercises, type of
load or resistance, number of sets and repetitions, frequency of exercise, and duration of rest periods. The choice of exercise involves the type of strength training that is to be used (isotonic, isometric, or isokinetic). It also involves the specific exercises that are used to gain the best results in the desired activities and body parts. This refers back to the specificity of exercise theory.

The order of exercise is determined according to muscle composition, joint complex, and the intensity of the exercise. Deschenes et al reported that large muscle group exercises should be performed before smaller muscle group exercises for the same body part. This is because it has been theorized that exercising the larger muscle groups first helps provide a greater stimulus to the involved muscles. Baechle and Pauletto both agreed with this and stated that high intensity, multiple-joint, structural, and large-muscle mass exercises should precede lower intensity, single-joint, isolation, and small-muscle mass exercises. Pauletto also reported that when doing more than one exercise per body part, the higher intensity exercise should be done while the athlete’s energy substrates are fresh.

The load or resistance used in strength training is most commonly a percentage of an individual’s 1 Repetition Maximum (RM), 3RM, 5RM, or 10RM. RM is the amount of weight lifted through the full range of motion for a given number of repetitions. Different load assignments will result in different outcomes. Baechle stated that “training with high intensities (above 80% of 1RM) produce more strength and power gains than do lower intensities (below 80% of 1RM), which tend to produce more hypertrophy and endurance (local muscular) gains.” An example of a strength training program that involves percent maximums is the DeLorme Strength Training Program which has the individual perform a set at 50% of 10RM, 75% of 10RM, and 100% of 10RM.

The number of sets and repetitions are variable to the specific type of strength training program involved. The number of sets can range anywhere from 1 to 10,
according to the specific program and its other variables. The most commonly used number of sets in strength training is 3 to 6 per exercise. The number of repetitions also varies according to the specific program. Most strength and power training programs utilize 3 to 8 repetitions. Kraemer warranted this by reporting that training at an 8RM and below develops the strength component while training at a 12RM and greater concentrates on endurance.

The frequency of training refers to the number of training sessions completed in a given period of time, usually one week. Workouts were originally performed on a three day per week (Monday, Wednesday, Friday) schedule. Deschenes et al reported that this schedule has been found to be adequate for proper muscle recovery. Presently, many lifters are training anywhere from 3 to 6 days a week. A study performed by Westscott reported that “there is no significant difference in strength gains between training 1, 2, 3, or 5 days per week when the total volume of work was kept at a constant.” Training frequency is very dependent upon the individuals preference as long as there is a rest period of 48 to 72 hours between consecutive body part training for optimal muscle recovery.

Finally, the duration of rest periods between sets, which is the primary topic of this study, is also varied according to the program involved. Rest periods can range from 60 to 90 seconds to 6 to 8 minutes in length. Most reliable sources on strength training today state that a rest period of 3 to 5 minutes is optimal for phosphagen (Adenosine Triphosphate (ATP) and Phosphocreatine (PC) restoration and strength increases. This topic will be addressed in more detail later in this study.

Muscular fatigue is one of the major contributing factors of decreases in strength during training. It is also one aspect that is not fully and truly understood. Muscular fatigue is defined as “the transient decrease in performance capacity of muscles when they have been active for a certain time, usually evidenced by a failure to maintain or develop a certain expected force or power.” Edward and Gibson stated that changes in muscle
function associated with fatigue may be loss of force or power output, slowing of relaxation, changes in muscle contractile characteristics, and alterations in electrical properties. These changes may have detrimental effects on strength training.

There are several theories of the causes or contributing factors of muscular fatigue. Two popular theories are the depletion hypothesis and the accumulation hypothesis. The depletion hypothesis is the idea that there is a depletion of glycogen or energy substrates in the muscle which leads to increased fatigue. This theory applies to all types of training, but is extremely obvious in sustained or longer duration exercises commonly utilized in endurance training. The accumulation hypothesis is the idea that, during training, there is an accumulation of waste products, such as lactic acid and hydrogen (H⁺) ions, which disrupts the excitation-coupling of muscle cells by decreasing blood pH and limiting enzyme activity. Wright and Tesch documented that accumulation of waste products also interferes with cross bridge formation in the muscle cells by competing with the calcium (Ca²⁺) on troponin's binding sites. This accumulation causes the muscle fibers to no longer respond to stimulation. The accumulation hypothesis applies more strongly to short term, high intensity exercises such as those utilized in strength training.

Other hypothetical causes of fatigue have been attributed to central inhibition (involving the CNS), peripheral inhibition (alterations within the skeletal muscle fiber-sarcoplasmic reticulum, proteins, etc.), and neuromuscular junction failure.

Bioenergetics involves the sources of energy utilized in muscle contraction. Strength training is a high-intensity, short duration exercise and primarily involves anaerobic energy substrates. The substrates involved in strength training are the phosphagens (ATP-PC), Lactic Acid Energy Source (LAES), and glycogen. The phosphagens are the primary source of energy in short duration, high power events, such as those involved in strength training. They are stored within the muscles and are ready for immediate use. Two distinct advantages of the phosphagens in strength training are: 1) immediate availability and 2) a large amount of energy per unit time.
disadvantage is that there is a limited supply of both components, which in turn leads to a limited amount of energy. The phosphagens are exhausted after approximately 5 to 30 seconds of work. Replenishment of the phosphagens starts immediately after the exercise is completed. Kraemer noted that 50% of the phosphagens are replenished within 30 seconds after completion of the exercise. During rest, excess oxygen consumption is used aerobically to produce ATP. Some of this ATP is stored directly in the muscles. The rest is broken down into Adenosine Diphosphate (ADP) and phosphate (P), and the energy released is used to bind the P and creatine into phosphocreatine. There are varying rates of this process documented in many sources. Allsen reported the phosphagen repletion process is completed within 3 to 5 minutes after the completion of exercise. See Table 1 for the rate of repletion of phosphagen stores.

The LAES, as the name implies, involves the accumulation of the waste product lactic acid. It involves the process of anaerobic glycolysis, which includes the splitting of glucose and the production of ATP and lactic acid. This energy source is the major supplier of ATP in workouts of 1 to 3 minutes such as long sets to failure, sets with short rest periods between them, and running distances of 400 m. The LAES cannot supply as much energy per unit of time as the phosphagens, and therefore, it is not as powerful.

The replenishment of the LAES involves the removing of the lactic acid from the muscles and blood. Sixty percent of the lactic acid is metabolized by the body tissues such as skeletal muscle, cardiac muscle, the kidney, liver, and brain. The remaining 40% is converted to glucose, protein, or is excreted out in the urine or sweat. The repletion process takes approximately 1 hour and 15 minutes. The lactic acid can also be aerobically metabolized and can supply ATP during light activity such as walking and stretching. This has led to the idea of performing light activity after a workout or between sets to clear out excess lactic acid.

Glycogen is a stored carbohydrate within the muscles and in the liver. There is approximately a total of 300 to 400 g of glycogen in the muscles and 70 to 100 g in the
Table 1. Replenishment of Phosphagen Stores

<table>
<thead>
<tr>
<th>Rest Time</th>
<th>Percent of Phosphagens Replenished</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 minute</td>
<td>75.00</td>
</tr>
<tr>
<td>2 minutes</td>
<td>93.75</td>
</tr>
<tr>
<td>3 minutes</td>
<td>98.44</td>
</tr>
<tr>
<td>4 minutes</td>
<td>99.61</td>
</tr>
<tr>
<td>5 minutes</td>
<td>99.90</td>
</tr>
</tbody>
</table>

liver. Muscle glycogen is utilized in high-intensity, short duration exercises, where as, liver glycogen is used more in low-intensity training. Muscle glycogen can be depleted as much as 20 to 50% during strength training, especially in type II muscle fibers. The repletion of glycogen is dependent on postexercise carbohydrate consumption. Optimal ingestion of carbohydrates is 0.7 to 3.0 g per kilogram of body weight taken every two hours after exercise. Repletion at this rate will be 5 to 6 umol per gram of wet muscle mass per hour for 4 to 6 hours. This may take longer if a high eccentric component is involved possibly due to the high rate of microtraumatic tearing of the muscle fibers.

As mentioned earlier, the length of the rest period between sets is a vital component or variable to take into account in strength training. The length of the rest period is dependent upon two things: 1) the type of training and 2) the energy source being used. The type of training depends on whether the training is for strength, endurance, or hypertrophy. This study will focus on strength training. The energy sources involved are ATP-PC, LAES, and glycogen, as mentioned earlier in relation to fatigue. Strength training, which primarily involves the phosphagens (ATP-PC) for energy, achieves maximal gains with rest periods of 3 to 5 minutes. Johnson verified this in a study he performed with rest intervals of 0.5 minutes, 1.5 minutes, and 3.0 minutes. The data supported the concept that longer rest periods produced greater increases in maximum strength than shorter rest periods. Li et al reported in a study of grip strength that subjects who had a 2 minute rest period consistently produced greater torque on subsequent grip strength measures than those with rest periods of 15, 30, and 60 seconds. Fleck and Kraemer, Allsen, and Lillegard et al documented that when training with the ATP-PC energy source, at least 2 to 3 minutes of rest are necessary between sets to replenish this energy source. Zatsiorsky opposes the majority by saying that rest periods of 4 to 5 minutes are not adequate for complete recovery and that rest periods of 10 to 15 minutes can be utilized. Pauletto contradicts this by reporting that resting longer than 5 minutes will cause the athlete to
cool down, which leads to an increased chance of injury. Therefore, the predominance of sources declare that optimal strength gains are achieved with rest periods lengths of 2 to 5 minutes; the amount of time it takes the ATP-PC in the muscles to replenish and below the time at which there is an increased chance of injury.

The purpose of this study was to measure the percent of recovery in the quadriceps muscles after a specified rest period of 1 minute, 2 minutes, and 3 minutes. It was performed to obtain the optimal rest period length between sets for strength training. The results of this study were expected to validate current literature that rest periods of 2 to 5 minutes produce optimal results in strength training.
CHAPTER II
METHODS

Subjects

This study involved twenty-four (12 male, 12 female) randomly chosen subjects between the ages of 18-35 years old (mean 23.96, standard deviation 2.29). The subjects met specific criteria of not performing lower extremity strength training in the past two months. The subjects also had no histories of cardiovascular problems or orthopedic or neuromuscular problems of the hips or knees. They were informed of the purpose of the study and their rights as human subjects. Approval of participation was attained by the signing of an Institutional Review Board approved consent form in the presence of a witness, other than the principal investigator (Appendix). The subjects were randomly placed into three groups of eight, each containing four males and four females. The groups were named Group 1, Group 2, and Group 3. The name of the group signified the interset rest period length in minutes for that particular group.

Procedure

The procedure involved two sessions. During the first session, the subjects were instructed on a lower extremity warm-up consisting of 3-5 minutes on an exercise bicycle and quadriceps and hamstring stretching (Appendix). Next, the subject’s dominant lower extremity was determined by a procedure which involved having the subject hop on one leg. The leg on which the subject hopped was determined as dominant and was the leg tested in this study. The subjects were then positioned according to KIN-COM (Chattanooga Inc., Chattanooga, TN) pre-set position guidelines for unilateral isokinetic knee extension. They were positioned seated with: 78 degrees of recumbence;
2” clearance from seat pan to popliteal space; one support strap across the waist and one diagonally across the trunk from contralateral shoulder down; joint axis of dominant knee in line with the axis of the rotational arm; double shin pad 1/4” to 1/2” proximal to malleoli with rigid side on shin; thigh support on ipsilateral thigh 2” from greater trochanters; and hands holding lateral borders of the seat pan. The protocol used was concentric knee extension set at a speed of 90 degrees/second with a submaximal concentric return. The range of motion was from 85 degrees of knee flexion to 10 degrees from full extension for a total of 75 degrees. After the individual subject’s position was programmed into the KIN-COM computer, a trial run of six repetitions was completed so that the subjects would become familiar with the motion and speed of the exercise. The participants were also instructed to follow the verbal commands of the investigator. The subjects extended their legs upon hearing the verbal command “KICK!” The subjects then returned to the start angle (85 degrees) submaximally. After a short pause, the subject extended the leg upon hearing “KICK!” again. This was done to reduce cheating by eliminating the use of momentum and stretch reflexes. This was repeated for the six repetitions in both sets.

The second session was the time of actual data collection. First, the subjects performed the specified warm-up. Then, each individual subject’s position was rechecked for accuracy. If there were inconsistencies in the position, they were corrected to meet the KIN-COM positioning guidelines. Next, there was a review of the proper technique and verbal commands. The subjects then performed a submaximal warm-up of six unilateral isokinetic knee extensions. The subjects then performed the actual test of six repetitions of unilateral isokinetic knee extension at 90 degrees/second on the KIN-COM machine. Then, depending on the group assignment, the appropriate interset rest period length was timed with a chronometer. After the specified rest period, the subjects then repeated the six repetitions of unilateral isokinetic knee extension in the same fashion. The peak torque was electronically recorded by the KIN-COM for both sets.
Data Analysis

Analysis of the data was performed using the Statistical Package for Social Sciences (SPSS) computer program. The percent of original peak torque was calculated by dividing the peak torque of trial 2 by the peak torque of trial 1 for each individual in the three groups. All numbers were rounded to the nearest tenth. An independent analysis of variance was used to compare the percent of recovery in the three groups.
CHAPTER III
RESULTS

There were no significant differences in the percent of recoveries between the three groups of interset rest period lengths $F(2,21) = 0.94, p<.05$. The results of trail 1 and trial 2 for the three groups are summarized in Figure 1, Figure 2, Figure 3, and Figure 4. The percent of recovery for the three groups were: Group 1 (1 minute interset rest period length) had a mean percent of recovery of 100.72%; Group 2 (2 minute interset rest period length) had a mean percent of recovery of 97.84%; and Group 3 (3 minute interset rest period length) had a mean percent recovery of 102.08% (Figure 5, Figure 6).

There were also no significant differences in the percent of recovery between gender in the three groups $F(1, 22) = 2.48, p<.05$. The mean percent of recovery for males in Group 1 was 96.16% and the mean percent of recovery for females was 105.27%. The mean percent recovery for males in Group 2 was 96.89% and the mean percent recovery for females was 98.80%. The mean percent recovery for males in Group 3 was 101.71% and the mean percent of recovery for females was 102.45%. The results of the percent of recovery in gender was consistently higher for females than males in all three groups. The difference in mean percent of recovery between the genders is summarized in Figure 7.
Figure 1

Participants' Peak Torque in Trial 1

Identification Number
Figure 2

Mean Peak Torque of Trial 1

Ft-lbs

1.00 2.00 3.00

Group
Figure 3

Participants' Peak Torque in Trial 2

Identification Number
Figure 4

Mean Peak Torque of Trial 2

Ft-lbs

Group

1.00 2.00 3.00
Figure 6

Percent Recovery per Group

Mean % Recovery

Group

103
102
101
100
99
98
97

1.00
2.00
3.00
Figure 7

Mean Percent Recovery per Gender

Gender

Female 1.00
Male 2.00
CHAPTER IV
DISCUSSION

When training for strength, sufficient rest between sets is important to maximize training results. Reviews of literature have reported that the longer interset rest period length, the greater chance of increases in strength. This is theorized based on the recovery rate of the phosphagen energy source, which is the primary energy source utilized in short duration exercises as those involved in strength training.

The purpose of this study was to find the optimal interset rest period length between sets of unilateral isokinetic concentric knee extension involving the quadriceps muscles in strength training. Allsen reported ATP-PC stores should recover 75.00% after 1 minute, 93.75% after 2 minutes, and 98.44% after 3 minutes (Table 1). Allsen's data was supported by Baechle and Pauletto who also reported that 3 to 5 minute interset rest period lengths were optimal for phosphagen recovery. Johnson et al warranted this in their study on the effects of different rest intervals in strength training. They found that interset rest period lengths of 3.0 minutes produced greater increases in strength than 1.5 minutes and 0.5 minutes.

The results of this study do not correlate with the reviews of literature. The results of this study were: Group 1 had a mean percent of recovery of 100.72%; Group 2 had a mean percent of recovery of 97.84%; and group 3 had a mean percent of recovery of 102.08%. It shows no significant differences between the three groups of interset rest period lengths. Therefore, this study reports that interset rest period lengths of 1 minute are adequate for recovery of the quadriceps muscles in strength training for both males and females.
The most plausible reason for the results of this study failing to correlate with the review of the literature is that the sources used concentrated on isotonic strength training, whereas, this study utilized isokinetic strength training. Sources report that isokinetic training is preferred over isotonic training for increasing strength and motor development, but they do not report how recovery times differ following each type of muscle contraction. The results of this study may imply that there is a faster rate of recovery of the quadriceps muscles following isokinetic contractions rather than isotonic contractions.

There were a few areas of interest found when analyzing the data of this study. In Group 1, the female subjects recorded higher peak torques on trial 2 than they recorded on trial 1. In Group 2, two female subjects and one male subject recorded higher peak torques on trial 2 than on trial 1. In Group 3, three female subjects and two male subjects recorded higher peak torques on trial 2 than they recorded on trial 1. This presents as a percent of recovery of over 100%. There are three reasonings for why this phenomenon may have occurred: 1) the subjects did not perform the exercise with full effort on trial 1; 2) the involved exercise was unable to fatigue the subjects’ muscles; and 3) neural learning and recruitment played a positive role for increased torque production in trial 2.

Dominance is another area where the results were not significant but were worth mentioning. Of the twenty-four subjects, only six were left side dominant. The mean percent of recovery of the left side dominant subjects was 96.01% and the mean percent of recovery of the right side dominant subjects was 101.61%. The results are summarized in Figure 8.

There were many limitations to this study. The sample size was a major limitation. Future studies may wish to include a larger sample size. This would give a broader spectrum of results and decrease possibility of skewed results. Another limitation was the number of sample groups. Researchers may wish to use a larger variety of rest period lengths, such as differences of 5 seconds (5 seconds, 10 seconds, 15 seconds, etc.) from a no rest period group to as much as a 8 to 10 minute rest period group. Another limitation
Figure 8

Mean Percent Recovery per Dominance

Mean % Recovery

Dominance

Left 1.00

Right 2.00
was the lack of knowledge of the fiber type composition of the subjects. Muscle biopsies to find subject’s fiber type predominance (Type I vs. Type II) may prove beneficial in future studies. Finally, future studies may develop procedures to bring the subjects to 100% fatigue so that the phosphagens are completely exhausted and recovery starts from absolute zero.
CHAPTER V
CONCLUSION

Clinical Implication

The clinical implication of this study is that it will assist physical therapists in designing lower extremity strength training programs for their patients. It addresses the training variable rest period length, which is one of the six variables necessary for proper program development. This study provides physical therapists with the time necessary for phosphagen recovery of the quadriceps muscles when using isokinetic resistance training methods. This study reports that interset rest period lengths of 1 minute are adequate for recovery of the quadriceps muscles in strength training for both males and females.
In this experiment, subjects will perform the specified protocol on the Kin-Com machine. The Kin-Com is a computerized piece of equipment routinely used in physical therapy for assessment and rehabilitation. Peak torque of isokinetic knee extension is the measurement used for this experiment.
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.)

Session 1:
During the first session, the subjects will be informed on the proper use of the Kin-Com and the correct technique for the involved exercise, isokinetic (controlled speed) knee extension. The subjects will be taught stretching and a proper warm-up to reduce chance of injury, such as muscle strains. The subjects will then be given adequate practice to perfect necessary form.

Session 2:
During the second session, the subjects will perform 6 repetitions of unilateral isokinetic knee extension at 90 degrees/second on the Kin-Com machine. The machine will determine the peak torque produced by the subjects during the exercise. The subject will then repeat the 6 repetitions on the Kin-Com, and the peak torque will again be determined.
3. BENEFITS: (Describe the benefits to the individual or society.)

This study will help physical therapists to facilitate and promote healing and strength gains in the most efficient manner.

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 psychological, 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.)

Like most studies, there is a potential for risks to occur. An example may include muscle strains, although the likelihood is remote since the involved exercise and equipment are routinely used in physical therapy.

In order to minimize the chance of risks, this experiment will include thorough subject education and monitoring during the treatment. This will include education on a proper warm-up, stretching, and exercise technique. The investigators will be highly skilled with the use of all equipment and procedures. Finally, equipment quality will be assured by routine maintenance and calibration.

All personal information (names, addresses, etc.) will be collected confidentially and safely locked in the Physical Therapy Department of the UND School of Medicine for 3 years following the completion of this experiment.

After each scheduled data collection, individual results will be reviewed privately with the subject.
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.

See attached consent form.

Consent forms and all data will be safely locked in the Physical Therapy Department of the UND School of Medicine for 3 years following the completion of this study.

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

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

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

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

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

SIGNATURES:

Principal Investigator

DATE: ____________________

Project Director or Student Adviser

DATE: ____________________

DATE: ____________________
INFORMATION AND CONSENT FORM

Title: The Effect of Interset Rest Period Length on Quadriceps Muscle Recovery in Strength Training

You are being invited to participate in a research study conducted by Jesse J. Wosick, a physical therapy student at the University of North Dakota. This project is focusing on the recovery of the quadriceps muscles. These muscles are located in the front of the thigh and function to extend or straighten the knee joint of the leg. The purpose of this study is to measure the percent of recovery of the quadriceps muscles after specified rest periods to find the optimal rest period length between sets for strength training.

Participants need to be between the ages of 18-35 and meet the criteria of not performing strength training of the lower extremities in the past 2 months. They must also have no history of cardiovascular problems and/or orthopedic or neuromuscular problems of the hips and/or knees. The subjects will be randomly placed into Group 1, Group 2, or Group 3. The group name represents the rest period length in minutes between exercises.

You will be asked to participate in a 2 week program. The program will involve 2 sessions, each approximately 20-30 minutes long. The first session will be used for the subject to become familiar with and to practice with the equipment involved. The second session will involve performing 6 repetitions of isokinetic (controlled speed) knee extension at a set speed of 90 degrees/second on a Kin-Com machine. The machine will register the peak torque, which is the greatest amount of force you exerted during the exercise. Then, depending on the group you have been randomly placed in, you will rest for a specified time. After the rest, you will be asked to repeat the exercise. Your peak torque will again be recorded.

Like most studies, there is a potential for risks to occur. An example may include muscle strain, although the likelihood is remote since the involved exercise and equipment are routinely used in physical therapy. Proper procedures will be used to minimize all risks. In the event that activity in this experiment results in physical injury, first aid will be available.

Personal information (name or any other information disclosed by the subjects) will not be used in reports. All information and data will be collected confidentially and locked in the Physical Therapy Department at UND for security.

I will be available to answer any questions you may have or that may arise during the study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. For further information call Jesse J. Wosick at (701) 777-9660 or Mark Romanick at (701) 777-2831. A copy of this information and consent form is available to all participants.
I have read all the above information and fully understand the requirements of both parties. I understand I may ask questions at any time during the experiment and may withdraw my participation without consequence. I meet the criteria for the experiment and am a full and willing participant.

Participant’s Signature
Date

Witness
Date
Stretch hamstring uni longsitting.

- Sit on firm surface with one leg out in front.
- Slowly lean forward, trying to touch toes.

Rest 30 Seconds between sets.
Hold exercise for 25 Seconds.
Perform 1 set of 3 Repetitions, once a day.

---

Stretch Quads prone self

- Lay face down.
- Reach back and grasp ankle.
- Relax leg and gently pull ankle towards buttocks.

Rest 30 Seconds between sets.
Hold exercise for 25 Seconds.
Perform 1 set of 3 Repetitions, once a day.
REFERENCES


