1997

An Electromyographic Study of Back and Lower Extremity Muscle Activity during a Traditional Squat and the Plyo Press Leg Press

Heidi C. Ivesdal

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/228

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 zeineb.yousif@library.und.edu.
AN ELECTROMYOGRAPHIC STUDY OF BACK AND LOWER EXTREMITY MUSCLE ACTIVITY DURING A TRADITIONAL SQUAT AND THE PLYO PRESS LEG PRESS

by

Heidi Cristine Ivesdal
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 Heidi Cristine Ivesdal 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  An Electromyographic study of Back and Lower Extremity Muscle Activity during a Traditional Squat and the Plyo Press Leg Press

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 absence, by the Chairperson of the department. It is understood that any copying or publication or other use of the Independent Study Report or 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  [Signature]

Date  1-2-97
<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Figures ................................................................. vi</td>
</tr>
<tr>
<td>List of Tables ................................................................. vii</td>
</tr>
<tr>
<td>Acknowledgments ................................................................. viii</td>
</tr>
<tr>
<td>Abstract ................................................................. ix</td>
</tr>
<tr>
<td>Introduction ................................................................. 1</td>
</tr>
<tr>
<td>Review of the Literature ........................................................... 4</td>
</tr>
<tr>
<td>Electromyography ................................................................. 4</td>
</tr>
<tr>
<td>Typical Muscle Activity ........................................................... 4</td>
</tr>
<tr>
<td>Specific features of the Plyo Press design ................................... 5</td>
</tr>
<tr>
<td>Similar training devices ........................................................... 7</td>
</tr>
<tr>
<td>Training options ................................................................. 8</td>
</tr>
<tr>
<td>Purpose ................................................................. 9</td>
</tr>
<tr>
<td>Methods ................................................................. 10</td>
</tr>
<tr>
<td>Subjects ................................................................. 10</td>
</tr>
<tr>
<td>Instrumentation ................................................................. 11</td>
</tr>
<tr>
<td>Procedure ................................................................. 11</td>
</tr>
<tr>
<td>Data Analysis ................................................................. 15</td>
</tr>
<tr>
<td>Results ................................................................. 17</td>
</tr>
<tr>
<td>Plyo Press leg press vs. traditional squat .................................... 17</td>
</tr>
<tr>
<td>Plyo Press plyojump vs. the other exercises .................................. 17</td>
</tr>
<tr>
<td>Timing of EMG activity ........................................................... 20</td>
</tr>
<tr>
<td>Discussion ................................................................. 24</td>
</tr>
<tr>
<td>EMG normalization ................................................................. 24</td>
</tr>
<tr>
<td>Plyo Press leg press vs. squat .................................................. 24</td>
</tr>
<tr>
<td>Plyo Press plyojump vs. other exercises ....................................... 26</td>
</tr>
<tr>
<td>Clinical Implications of using the Plyo Press ................................ 27</td>
</tr>
<tr>
<td>Section</td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td>Conclusions</td>
</tr>
<tr>
<td>Appendices</td>
</tr>
<tr>
<td>Human Subjects Review Form</td>
</tr>
<tr>
<td>Institutional Review Board Form</td>
</tr>
<tr>
<td>Consent Form</td>
</tr>
<tr>
<td>References</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. EMG activity for all three exercises</td>
<td>18</td>
</tr>
<tr>
<td>2. EMG activity in muscle groups during the <em>Plyo Press</em> leg press in relation to time and knee range of motion (Subject no. 8)</td>
<td>22</td>
</tr>
<tr>
<td>3. EMG activity in muscle groups during the squat in relation to time and knee range of motion (Subject no. 8)</td>
<td>23</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table:                                                                 Page:

1. Subject demographic characteristics......................................................... 10
2. Average %MVC for all three exercises.......................................................... 19
ACKNOWLEDGMENTS

I would like to thank all the wonderful people who helped make this study happen. My classmates, Joel Anderson and Melanie Michaels, who took time out of their schedules to assist in running my subjects were a tremendous help. The subjects who participated in my study were instrumental, for without them this project would not have existed. My advisor, Dr. Thomas Mohr, was an incredible help and he spent many hours teaching me the finer points of computers. My fiancé, Troy Ivesdal, was so supportive and understanding and I could not have finished this project without his motivation.
ABSTRACT

Strength training is a primary factor in athletics and rehabilitation. Lower extremity strength training has traditionally consisted of free weights, biomechanically designed weight machines, or plyometrics. The Plyo Press is a new machine that is currently being utilized in the Frappier Acceleration Program for athletes. It is specifically designed for lower extremity strength training in combination with plyometrics. The principle behind its design is to build strength in the most effective way to enhance speed and dynamic activity without the stress to the low back or legs that is present with the use of free weights.

Because the Plyo Press is newly designed there has been limited research conducted on the machine to validate the manufacturer’s claims. Therefore, the purpose of this study was to compare muscle recruitment during a free weight squat lift, a leg press in the Plyo Press leg machine, and a plyojump in the Plyo Press machine. EMG analysis was performed on selected trunk and lower extremity muscles in order to provide information on the muscle activity and recruitment pattern evoked by the Plyo Press.

Fifteen healthy male subjects were loaded down with 80% of their previously determined 1 Repetition Maximum and performed three repetitions of each exercise.
An analysis of the normalized EMG data was conducted using the Myosoft and Norquest software package.

The results of this study revealed that the Plyo Press appeared to specifically recruit the vastus lateralis muscle during each of the exercises. The Plyo Press appears to offer the advantage of specifically training the vastus lateralis muscle while minimizing the recruitment of other lower extremity and back muscles.
CHAPTER I

INTRODUCTION

A variety of training programs and techniques are currently being used to improve an athlete's ability by increasing strength and power. Strength (the ability of a muscle to generate force against resistance)\textsuperscript{1,2} can be improved by forcing the muscle to work at a higher level than to which it is accustomed. Power (the ability to exert force at higher speeds)\textsuperscript{1,2} can be improved in two ways: 1) by increasing strength, and 2) by decreasing the time required to produce the strength. It has been said that achieving improvements in the power component of fitness is indicative of success in sports requiring dynamic movement and excessive force production.\textsuperscript{3}

A great amount of muscle activity occurs in dynamic activity, which uses a combination of both strength and power. This dynamic activity is utilized in most sports and therefore, needs to be addressed when training an athlete to prepare for the demands of his or her sport. One training technique that involves dynamic activity is plyometrics. Plyometrics (exercises that enable a muscle to reach maximal strength in as short a time as possible) are quick, powerful movements that pre-stretch a muscle eccentrically (activating a stretch-shortening cycle) to produce a strong concentric contraction.\textsuperscript{2} This dynamic activity uses the force of gravity to store energy in the muscles which is used to produce a strong contraction.\textsuperscript{1,2,6,7} A major
The goal of plyometric training is the ability to rapidly apply a force by decreasing the amount of time between the eccentric muscle contraction (landing) and the concentric contraction (jumping). Thus plyometrics are used in training protocols to overload a muscle to improve the strength and power of that muscle.\textsuperscript{1,2}

The \textit{Plyo Press} (Acceleration Products, Inc., Fargo, ND 58103) is a machine that was specifically designed to efficiently train the lower extremity for strength and power. This machine can improve power by combining both strength training and plyometrics at the same time.\textsuperscript{9} The \textit{Plyo Press} works similar to a leg press exercise (lifting and lowering a load from 90 degrees of knee flexion to full knee extension and back to 90 degrees) but adds a plyojump maneuver (a vertical jump against resistance while on the trolley). The \textit{Plyo Press} is advertised as being superior to other strengthening devices (ie. Cybex Eagle equipment, hip sled, and free weights) because it was designed to train athletes using dynamic exercise to build strength in ways that benefit both speed and power.\textsuperscript{9} Also important is that it virtually eliminates the potential injuries that can result from training with the other devices, because it controls the load that is placed on the body.\textsuperscript{9}

In order to verify to claims made by the manufacturer, research needs to be conducted on the \textit{Plyo Press} that mimics the intense training performed by competitive athletes as well as the sub-maximal training of the recreational athlete or patient. One previous study looked at the muscle activity of similar muscle groups during the performance of exercises at a weight equal to the subjects body weight.\textsuperscript{20} The purpose of this research study was to compare the muscle activity, through the
use of electromyography, of selected back and lower extremity muscles during a *Plyo Press* leg press, a plyojump, and a traditional free weight squat at a weight equal to 80% of the subject's one repetition maximum.
CHAPTER II
REVIEW OF THE LITERATURE

Electromyography

Electromyography (EMG) is the study of muscle function through analysis of the electrical signal that the muscle elicits.\(^\text{13}\) EMG is used to measure activity of a selected contracting muscle, and provides an insight of the force developed by a muscle. Vakos et al\(^\text{5}\) states that increased EMG activity in a muscle suggests increased force production by that muscle, but force generated by that muscle cannot be directly calculated from EMG. However, the relationship between integrated EMG and muscle force is generally linear.\(^\text{5}\)

Typical Muscle Activity

The vastus lateralis (VL) is a powerful extensor of the knee joint.\(^\text{13}\) During a squat or leg press the knee has to extend to complete the pattern of movement. As the knee moves from flexion to extension, with moderate resistance or during rising, the levels of EMG activity go from high to low respectively.\(^\text{10}\) Although the VL is active throughout knee extension, it is more active when the hip, knee, or both is flexed,\(^\text{13}\) as is seen is a leg press or squat.

The biceps femoris (BF) acts both on the hip and knee joints.\(^{1,2,5,10,13,14}\) The muscle is active during hip extension and knee flexion regardless of which joint is
moving. However, the level of activity is low as compared to the VL when the knee is moving from flexion to extension during rising. The EMG activity does increase slightly during the second half of rising from a flexed knee position.

In contrast to the BF, the gluteus maximus (GM) is only active during resisted hip extension and is also a major lateral rotator of the hip. It is also active during trunk extension. The GM activity recorded during rising from a squat showed higher activity during the middle portion of the lift and lower activity during the beginning and the end of the lift.

The erector spinae's (ES) prime action is extension of the spine, especially when returning from a forward flexed position. In order to decrease the ES muscle activity and the stresses placed on the spine in the flexed position, the manufacturers of the Plyo Press added a back support that will place the spine in its normal lordotic position during the leg press. The preferred lordotic position during rising from a squat puts less stress on the inert structures of the low back thus decreasing injury to these painful structures.

**Specific Features of the Plyo Press design**

The specific features of the Plyo Press that were devised to keep the injury rate down and improve the strength and power include: the use of cams, an inclined sled, an elongated sled track, and an inclined foot plate. The three cams are designed to vary the load linearly as the knee goes from 90 degrees flexion to full knee extension. When the knee is flexed to 90 degrees the load is 80%, at 45 degrees the load increases to 100% and in full knee extension the load is at 120%. The sled
supports the upper body and back and is inclined at a 15 degree angle from the horizontal. This allows redirection of the flexor loading moment of the knee, and thus reduces the stress placed on the joints of the back, hip, and knee.\textsuperscript{10,11,12}

The elongated sled track and inclined foot plate are very important in the plyometric exercises that are performed on the \textit{Plyo Press}. The length of the sled track is 108 inches which enables an athlete to perform a plyojump of greater distance than would be allowed by other leg press machines. The manufacturer claims that this unique ability to perform plyometric jumps with varying amounts of resistance can greatly improve an athlete’s strength and power.\textsuperscript{9} The foot plate is angled 15 degrees from the vertical which places the athlete’s foot in plantarflexion whenever the foot is in contact with the foot plate. This plantarflexion somewhat forces the knee into flexion when landing during the plyojump activity and thus prevents hyperextension of the knee which can cause injury.

The \textit{Plyo Press} also has the ability to provide the athlete with resistance that is less than, equal to, or greater than, the athlete’s body weight.\textsuperscript{9} Therefore, this machine can be used for improving the strength and power of the athlete, and also for the rehabilitation of the injured athlete. The \textit{Plyo Press} was designed to decrease the strain on the low back while increasing quadriceps muscle function during plyometric exercise. The manufacturers of the \textit{Plyo Press} suggest it is a uniquely superior training device when compared with traditional free weights.
Similar training devices

There has been limited research conducted on the *Plyo Press* as well as similar training devices. However, a group of investigators have written several articles on the muscle activity and hip and knee load moments during rising on a machine that has some similar features of the *Plyo Press*.10,11,14 These characteristics include: a fixed back support on a moveable sled, a slightly inclined foot plate, and variable resistance. The movements of both machines are similar in that they both require the subject to commence the movement from knee flexion, extend the knee against resistance while rising, and returning to knee flexion.

Similar muscles were studied (rectus femoris, vastus lateralis and medialis, biceps femoris, semimembranosus/tendinosus and gastrocnemius) and their EMG activity was discussed. During the knee extending phase of the lift, this study revealed that the quadriceps activity levels were high at large knee angles and low at small angles.10 The HS activity levels were low in the final extending movement of the lift. When the device was loaded with higher resistance, there was a slightly higher activity in the quadriceps muscles.10

Because the devices are similar, the *Plyo Press* would be expected to perform in the same fashion and would show similar EMG muscle activity. James showed comparable muscle activity in her study of the *Plyo Press* with the resistance equal to the subject’s body weight.20
Training options

There are many training options available to today's athlete.\textsuperscript{1,2,18} Traditionally, free weight training has been used to increase strength. This involves lifting heavy weights for only a few repetitions.\textsuperscript{1,18} More recently many sports facilities have been incorporating plyometrics into their training program. Plyometrics are thought to increase the power component. One other option, discussed by Wilson et al.,\textsuperscript{18} combines both strength and power. It has been called dynamic weight training and serves to maximize mechanical power output. This is done by lifting relatively light resistance at high speed.

The \textit{Plyo Press} also combines the use of strength training in conjunction with plyometrics.\textsuperscript{9} The advantage of the \textit{Plyo Press} is that relatively high loads can be placed on the body, while still performing the plyometric jump (which is typically performed with the resistance of the athlete's body).\textsuperscript{2,7-9,18} Training with loads at 70%-90% of an athlete's one repetition maximum has been shown to greatly improve the strength gains of the trained muscles.\textsuperscript{18,19} If a machine such as the \textit{Plyo Press} can allow an athlete to perform a plyometric jump while working with a high resistance, it would then follow that the power component, which is so important in dynamic sport activities, would be improved.

Free weight training alone at resistances of 70%-90% of maximum would only improve the strength component and not the speed or power.\textsuperscript{18} Plyometric training by itself would only improve the muscular power and competitive performance, but the necessary strength gains would not be seen.\textsuperscript{18} Wilson et al.\textsuperscript{18}
concluded that to enhance dynamic athletic performance athletes should follow the optimal training strategy which is a hybrid between traditional weight training and plyometric training.

**Purpose**

Because there has only been one previous study performed on the *Plyo Press*, there needs to be further research conducted on this machine to confirm the claims made by the manufacturer. Therefore, an investigation of the activity of some major trunk and lower extremity muscles during the movements of the *Plyo Press* needs to be conducted in a manner that is more conducive to the higher resistance levels seen with athletic training. Thus, the purpose of this study was to compare the trunk and lower extremity muscle activity during a *Plyo Press* leg press, a plyojump, and a traditional free weight squat performed at 80% of the subject’s one repetition maximum. Of particular importance are the following: 1) the comparisons of the erector spinae activity during the exercises, as the low back is often injured when training at a high level of resistance and 2) the levels of lower extremity muscle activity elicited by the *Plyo Press*. 
CHAPTER III

METHODS

Subjects

Sixteen, healthy, male volunteers ranging in age from 19 to 27 years ($X = 22.07$) were recruited for this study (Table 1). All subjects satisfied the selection criteria, which required that each subject must: 1) have no hip, knee, ankle, or back musculoskeletal pathologies that would interfere with this study, or put the subject at risk for injury, 2) be currently participating in a weight training program at least one or more times per week, 3) be able to safely squat a weight equal to 80% of their 1 RM, and 4) be familiar with the Plyo Press machine and have previously used it in their weight training program.

Table 1.- Subject Demographic Characteristics

<table>
<thead>
<tr>
<th></th>
<th>AVERAGE</th>
<th>RANGE</th>
<th>STANDARD DEVIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE (years)</td>
<td>22.07</td>
<td>19-27</td>
<td>2.22</td>
</tr>
<tr>
<td>HEIGHT (inches)</td>
<td>73.5</td>
<td>68-77</td>
<td>2.60</td>
</tr>
<tr>
<td>WEIGHT (pounds)</td>
<td>224.4</td>
<td>178-293</td>
<td>35.08</td>
</tr>
</tbody>
</table>

The experimental procedure was explained to each subject as well as his rights as a participant in accordance with the Institutional Review Board at the University of
North Dakota and Medical Park. Each subject then signed an informed consent form prior to voluntary participation in the study (see Appendix).

**Instrumentation**

Electromyography (EMG) was used to determine the activity of selected low back and lower extremity muscles. A Noraxon Telemyo8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ, 85254) was used to collect the EMG data. A Penny and Giles M180 electrogoniometer (Penny & Giles Inc., 2716 Ocean Park Blvd, Santa Monica, CA, 90405) was used to measure the knee range of motion during the exercises. A Noraxon Telemyo8 receiver collected the telemetered information from the EMG electrodes and the electrogoniometer. This information was then digitized by a DT2801-Analog to digital interface board installed in a NET 486DX computer. The Myosoft data collection software that accompanies the Telemyo8 EMG system was used to collect the digitized EMG signal in a variety of forms, and the Norquest software was used to analyze the data.

**Procedure**

Electromyographic activity was collected in four trunk and lower extremity muscles on the right side of the body. Only the right-sided muscles were used because the EMG activity is symmetrical when loads are lifted in the midline. These muscles were the: 1) Vastus Lateralis (VL), 2) Biceps Femoris (BF), 3) Gluteus Maximus (GM), and 4) Erector Spinae (ES). These muscles were selected because of their probable involvement during the performance of the *Plyo Press* leg press, plyojump, and traditional free weight squat exercises.
Electromyographic activity was recorded through the use of pre-gelled silver-silver chloride surface electrodes (Multi Bio-Sensors, El Paso, TX 79913). The placement of the electrodes was around the motor points of the selected muscles, and was found by using a Respond Unit stimulator (Empi Inc., 1275 Gray Fox Road, St. Paul, MN 55112). The motor point was at the areas in the muscle belly that showed the greatest amount of isolated muscle contraction.

To reduce the skin impedance and ensure good contact with the electrodes, the skin at each electrode site was shaved of any hair, if needed, and then rubbed with alcohol. This was done according to the recommendations made by the author of prior EMG studies.13,15 Two electrodes were placed around the motor point of each muscle and one ground electrode was placed over the greater trochanter. The pairs of electrodes were arranged so that each one was in line with the muscle fibers of each of the four muscles as recommended for proper unit recording.15 The inter-electrode separation for each pair of electrodes was set at 1/2 inch, the recommended interval needed to maximize the EMG signal and minimize the amount of activity from extraneous muscles.12,15

The axis of the electrogoniometer was placed at the level of the knee joint on the lateral aspect of the right knee. The proximal arm of the electrogoniometer was placed parallel to the shaft of the femur, and the distal arm was placed parallel to the fibula. The electrogoniometer was adhered with double sided adhesive tape.
To record EMG and electrogoniometric activity, the EMG signals were transmitted from the surface electrodes and electrogoniometer to the receiver unit, and then into a computer for display. The EMG data for each subject was recorded by the computer, and stored on disk, for later analysis.

In order to normalize the EMG data for comparison of the selected muscles’ activity, each subject performed a maximal voluntary contraction (MVC) of each of the muscles. Because of the strength of the subjects, traditional manual muscle testing procedures could not be used to find the MVCs. Both the positions and techniques were altered so that each subject could perform a true MVC. The position for both the VL and the BF MVCs was seated on the edge of a plinth. A stabilization belt was placed around the ankle to hold the knee into 90 degrees of flexion. Each subject was then asked to perform knee extension and knee flexion, respectively. The MVC was held for approximately five seconds and the subject was given a rest period as needed. A multi-hip machine was used for the GM MVC. The subject stood on the platform of the machine and the posterior thigh was placed on the lever arm and held in approximately 10 degrees of hip extension with the knee flexed to 90 degrees. The lever arm was stabilized and the subject held the MVC for five seconds. The position for the ES MVC was seated on the Cybex back extension machine. The subject was put in approximately 15 degrees of lumbar flexion, the lever arm was stabilized, and the subject extended his back and held the MVC for five seconds. The MVC data for each muscle was recorded individually and stored by the computer.
The experimental activities consisted of three exercises which included: 1) a Plyo Press leg press, 2) a Plyojump (a vertical jump in the Plyo Press leg press machine), and 3) a traditional squat in a squat rack with free weights secured on a shoulder bar. Three repetitions of each activity was performed with a resistance equal to 80% of the subject’s previously determined 1 RM.

The starting position of each subject in the Plyo Press was with feet shoulder width apart and centered on the platform, with the hips and knees fully extended but not locked. Correct body position in the Plyo Press is determined by visualizing a straight line running from the posterior shoulder, through the anterior portion of the iliac crest, to the mid-arch of the foot. One repetition of the Plyo Press leg press and plyojump was determined to be from 0 degrees of knee extension, to approximately 90 degrees of knee flexion, and back to 0 degrees of knee extension. Each subject performed one trial of three repetitions for each exercise.

The traditional squat was performed in the squat rack with the subjects standing, and feet shoulder distance apart. The shoulder bar, with the weights equivalent to 80% of the subject’s 1 RM attached, was resting on the rack. The subject then placed the bar on his own shoulders by getting underneath the bar and standing up. Two spotters then stood by while the subject performed three repetitions of the traditional squat. One repetition was determined to be from 0 degrees of knee extension to 90 degrees of knee flexion and then back to 0 degrees of knee extension. The position of the knee in fullest flexion was spotted by an observer and the subject was told when to come back to knee extension. After the repetitions were performed
the subject placed the shoulder bar back on the rack with the help of spotters if needed.

**Data Analysis**

The two training techniques that were performed in this study were compared by analyzing the muscle activity: 1) during a *Plyo Press* leg press versus a traditional free weight squat, and 2) during a *Plyo Press* leg press, a plyojump, and a traditional free weight squat.

The data was taken from the second repetition of each exercise. The cycle of the repetition was from approximately 0 degrees of knee extension to peak knee flexion, and back to the fullest degree of knee extension for each activity. Despite the fact that the plyopress and plyojump start in knee flexion, the cycle for each of these was taken at knee extension so as to make them comparable to the traditional squat which starts in standing (knee extension).

The EMG data for each of the four muscles studied were normalized for all subjects individually, using the method performed by Vakos, et al.\(^5\) Initially, a maximal EMG signal intensity, in microvolts (\(\mu V\)), was calculated for each subject from the data collected during the MVC for each muscle. The MVC data was taken from the middle two seconds of constant contraction (not including ramping activity), and the mean of the 50 peak amplitudes was used as the MVC for each muscle. Average muscle activity was then determined for each exercise during the single repetition that was analyzed. The average %MVC was calculated using the following formula:
%MVC = \frac{\text{Average Muscle Activity During Exercise}}{\text{Average Muscle Activity During MVC}} \times 100

The range and standard deviation for each exercise was also calculated.
CHAPTER IV

RESULTS

_Plyo Press_ leg press vs. traditional squat

Table 2 shows the averaged normalized muscle activity obtained during the _Plyo Press_ leg press and the traditional squat at a resistance of 80% of the 1RM. The greatest amount of muscle activity occurred in the ES during the traditional squat (Figure 1). The average peak ES activity for the squat was 166.60% as compared to 102.87% for the _Plyo Press_ leg press. The VL muscle during the squat displayed the next highest amount of EMG activity. The average peak activity was 123.31% as compared to 118.50% for the _Plyo Press_ leg press. The GM and BF displayed the lowest EMG activity, with the squat showing slightly higher activity levels as compared to the _Plyo Press_ leg press.

During the _Plyo Press_ leg press and the squat, the VL and ES were the only muscles that elicited activity levels above the MVC. During the squat, the GM elicited activity at an average of 66.9% of the MVC, but the GM and BF for the _Plyo Press_ leg press and BF for the squat show levels below 40% of the MVC. (Figure 1)

_Plyo Press_ plyojump vs. the other exercises

Table 2 presents the average muscle activity elicited during all three exercises performed at 80% of the subject’s 1RM. The greatest amount of EMG activity for the
Figure 1. EMG activity for all three exercises.
Table 2.- Average %MVC for all three exercises

<table>
<thead>
<tr>
<th></th>
<th>Average %MVC</th>
<th>Percent difference from Leg press</th>
<th>Range</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vastus Lateralis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Press</td>
<td>118.50%</td>
<td></td>
<td>48.62-270.52</td>
<td>64.86</td>
</tr>
<tr>
<td>Squat</td>
<td>123.31%</td>
<td>+4.81%</td>
<td>54.64-321.80</td>
<td>67.28</td>
</tr>
<tr>
<td>Plyojump</td>
<td>139.73%</td>
<td>+21.23%</td>
<td>64.22-252.35</td>
<td>66.33</td>
</tr>
<tr>
<td><strong>Biceps Femoris</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Press</td>
<td>10.78%</td>
<td></td>
<td>3.03-20.86</td>
<td>5.24</td>
</tr>
<tr>
<td>Squat</td>
<td>37.86%</td>
<td>+27.08%</td>
<td>5.72-93.39</td>
<td>24.29</td>
</tr>
<tr>
<td>Plyojump</td>
<td>36.41%</td>
<td>+25.63%</td>
<td>9.43-86.93</td>
<td>23.12</td>
</tr>
<tr>
<td><strong>Gluteus Maximus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Press</td>
<td>35.56%</td>
<td></td>
<td>5.29-82.45</td>
<td>25.66</td>
</tr>
<tr>
<td>Squat</td>
<td>66.87%</td>
<td>+31.31%</td>
<td>15.41-259.93</td>
<td>63.07</td>
</tr>
<tr>
<td>Plyojump</td>
<td>71.67%</td>
<td>+36.11%</td>
<td>28.20-224.75</td>
<td>53.17</td>
</tr>
<tr>
<td><strong>Erector Spinae</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Press</td>
<td>102.87%</td>
<td></td>
<td>15.24-296.88</td>
<td>79.44</td>
</tr>
<tr>
<td>Squat</td>
<td>166.60%</td>
<td>+63.73%</td>
<td>34.11-372.26</td>
<td>103.52</td>
</tr>
<tr>
<td>Plyojump</td>
<td>134.04%</td>
<td>+31.17%</td>
<td>39.63-385.93</td>
<td>96.30</td>
</tr>
</tbody>
</table>
plyojump was found in the VL followed by the ES, GM, and BF. (Figure 1) The
plyojump elicited the greatest amount of VL muscle activity as compared to the squat
and leg press, whereas the greatest amount of ES muscle activity was found during
the traditional squat. The squat and the plyojump elicited very similar muscle activity
in the GM and BF. (Figure 1)

Overall, the *Plyo Press* leg press elicited the lowest level of muscle activity in
all four muscles monitored, but showed comparable levels of activity in the VL
during the plyojump and the squat.

**Timing of EMG activity**

The EMG activity of all four muscles throughout the knee ROM, (Figures 2
and 3) the *Plyo Press* leg press and squat show similar patterns of activity. From 0 -
90 degrees of knee flexion the VL activity shows a gradual increase with short
periods of higher activation. This phase would represent the eccentric portion of the
exercise, because the VL is lengthening as it is contracting. When the knee starts to
move back to extension from 90 - 70 degrees, the VL activity is at its highest level.
This phase would represent the concentric phase of the lift, because the VL is
shortening as it is contracting. The VL EMG activity then gradually decreases from
70 - 0 degrees (full knee extension).

The ES activity in the first 60 degrees of knee flexion shows minimal levels of
activity for the *Plyo Press* leg press and the squat. From 60 - 90 degrees there is a
slight increase in the leg press and a moderate increase during the squat. During both
exercises, the ES levels are at their highest from 90 - 60 degrees and then gradually taper off from 60 - 0 degrees of knee flexion.

The GM and BF patterns of activity are somewhat similar for both exercises. There is a gradual increase in activity from 0 - 90 degrees of knee flexion. Peak activity for both muscles during the leg press occurs from 90 - 60 degrees and then gradually decreases back to initial levels. Peak activity for the muscles during the squat occurs from 90 degrees back to full knee extension. The GM and BF EMG activity returns to the original level once the squat is completed.
Figure 2. EMG activity in muscle groups during the Plyo Press leg press in relation to time and knee range of motion (Subject no. 8).
Figure 3. EMG activity in muscle groups during the squat in relation to time and knee range of motion (Subject no. 8).
CHAPTER V
DISCUSSION

EMG normalization

In order to compare the individual subject's muscle activity, the EMG signals had to be normalized from a maximal voluntary isometric contraction (MVC). This is a procedure that is frequently used in EMG studies.\textsuperscript{5,10,21} It is based on the fact that an MVC is the greatest amount of effort that an individual can exert while contracting a muscle,\textsuperscript{13} and therefore, the MVC would elicit maximal firing levels of all the motor units of that contacting muscle. When analyzing the muscle activity during a specific exercise, the normalized values are often higher than the MVC values. This may be due to the difficulty in the standardization of testing the MVC\textsuperscript{10} and also the inability to effectively stabilize the subject while they are producing the excessive forceful contraction. This was a possible limitation to this study and therefore, the EMG normalization was used solely as an indicator of the levels of activation. Due to the mentioned limitations and the low numbers of subjects, data analysis was performed only through the use of descriptive statistics.

\textit{Plyo Press} leg press vs. squat

The EMG activity analysis of the \textit{Plyo Press} leg press and the squat revealed greater levels of activity in the four muscles during the performance of the
squat. (Figure 1) Because of the many studies that have been conducted analyzing the ES activity and its relationship to possible low back injury, the much greater level of ES activity during the squat is of particular interest. The average EMG level that the ES elicited during the squat was 166.6% as compared to 102.9% for the Plyo Press leg press. This increased activity level is possibly due to the dual use of the ES muscles during the squat. That is, they may be used both to assist in rising from a forward flexed position during the squat, and also to help support and stabilize the lumbar spine and pelvis.

The lower levels of ES EMG activity with the Plyo Press leg press are most likely due to the support that the sled gives to the lumbar spine and the maintenance of the low back in a neutral position on the sled. With the sled supporting the trunk and low back, the ES does not have to be used entirely as a stabilizer for the spine. This allows the muscles of the hips and knees to take most of the load during the lift and reduces load and tension on the spine. EMG levels and disc pressure have been observed to fall when the back of a subject is supported. With the low back in neutral the ES does not have to function to extend the trunk back from a forward flexed position. However, during the squat, the trunk is in a forward flexed position which moves the center of gravity forward and thus, increases the activity of the ES muscles and therefore increases disc pressure and the risk of back injury. Increased muscle activity in the ES also increases the risk for muscle strain.

In this study, the decreased levels of ES activity during the Plyo Press leg press are interpreted as being potentially beneficial by reducing the risk of injury to
the low back through muscular strain or intervertebral disc pathologies. Disc pathologies often occur due to an increase in intradiscal pressures. Intradiscal pressure increases two ways: 1) through compression of the spinal column as a result of the contraction of the muscles surrounding the spine or axial loading or 2) a change in body position such as forward bending of the spine. Therefore, decreased ES spinae activity should be beneficial by reducing stress on the disc. However, there is some research that supports the fact that increased activity in the ES is desired because it reduces the strain placed on the inert structures of the spine.

**Plyo Press plyojump compared to the other exercises**

The EMG activity of the four muscles during the Plyo Press plyojump show that the VL and GM levels were higher than those during the squat and Plyo Press leg press, whereas, the levels of the ES and BF are lower than the squat lift but higher than the Plyo Press leg press. (Figure 1)

The results of this study indicate that the Plyo Press plyojump should be beneficial in training an athlete. The plyojump effectively activates the VL as well as the ES, GM, and BF. The plyojump is a dynamic, explosive exercise which mimics activities seen during many sports. Because the plyojump is performed in the Plyo Press, the trunk and low back are supported throughout the exercise, which may help to decrease the low back injury seen during some lifting activities.
Clinical Implications of using the Plyo Press

The Plyo Press leg press can be used to train the athlete or patient needing specific quadriceps improvements while protecting the low back from undue stress. The cam and sled design allow resistance to be placed at a level that is less than, equal to, or greater than the subject's body weight. Therefore, an injured athlete or patient can use the Plyo Press during the rehabilitation process. The plyojump, which is dynamic and sport specific, can be performed on the Plyo Press, which should increase the intensity of the lower extremity exercise.
CHAPTER VI
CONCLUSIONS

1. The results of this study suggest that the *Plyo Press* leg press is a safe and effective piece of equipment for strengthening the VL.

2. The *Plyo Press* allows lower extremity strengthening to occur without increased levels of ES activity, thus decreasing possible risk of injury.

3. The *Plyo Press* enables an athlete to train at high resistance levels to improve the strength component of physical fitness.

4. The *Plyo Press* allows an athlete to use dynamic activity through the plyojump to enhance the power component of physical fitness.

The traditional free weight squat has been used historically to train the lower extremity for a variety of sports and recreational activities. Because of the high levels of ES activity seen during the squat, it may not be the exercise of choice for the training of younger athletes or those who have spinal pathology. Therefore, the *Plyo Press* leg press, with its lower levels of ES activity and high levels of VL activity, could be used to safely and efficiently train the lower extremity for strength and power.
Strength training is a primary factor in athletics and rehabilitation. Lower extremity strength training had traditionally consisted of free weights, biomechanically designed weight machines, or plyometrics. The Plyo Press is a machine specifically designed for strength training in combination with plyometrics. The principle behind its design is to build strength in the most effective way to enhance speed and dynamic activity without the stress to the low back or legs that is present with the use of free weights. The purpose of this study is to compare muscle recruitment during: 1) free weight squat lifting versus the Plyo Press leg press at 80% of IRM, and 2) a vertical jump versus a plyo-jump in the Plyo Press machine. Subjects will be loaded down with 80% of their previously determined 1 Repetition Maximum. We anticipate that 20 healthy male subjects will participate in this study. Selection criteria will ensure that each subject has no hip, knee, ankle, or back musculoskeletal pathology and can safely and appropriately squat 80% of his 1RM using free weight. Each subject will perform two exercises and two jump procedures. The exercises will include a free weight squat at 80% of 1RM and a Plyo Press leg press at 80% of 1RM. The jump procedures will consist of two vertical jump maneuvers, one standing unloaded and one in the Plyo Press machine at loaded at 80% of 1RM. The electromyographic(EMG) activity will be recorded for various lower back and thigh muscles and goniometric measurements will be taken at the hip and knee. We hope to benefit both athlete and patient populations by providing insight into new training methods in rehabilitation. Because we want to determine what benefits the Plyo Press can provide its users, it is necessary to perform this experiment with the use of healthy human subjects.
PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

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

SUBJECTS:

It is anticipated that we will recruit 20 healthy male subjects between the ages of 19-35 years. Criteria for selection will include that the subjects: 1) have no hip, knee, ankle, or back musculoskeletal pathologies that would interfere with this study or put the subject at risk for injury, 2) are participating in a strength training program (independently or supervised) at least one or more times per week, and 3) can safely and appropriately squat free weights at 80% of their 1 RM. The subjects will be recruited as volunteer subjects. This group of subjects will consist of 20 healthy males who are familiar with the use of the Plyo Press machine and have used it in their training program at some time.

METHOD:

We will measure the EMG activity of six muscles in the lower back and legs, as well as record range of motion of the hip and knee during all exercises being studied. We propose to measure EMG activity in the following muscles during weight lifting and jumping: 1) gluteus maximus, 2) erector spinae, 3) rectus femoris, 4) vastus lateralis, 5) biceps femoris, and 6) gastroc/soleus complex. These muscles have been shown to be active in lifting techniques in numerous studies.

To record the EMG activity, surface electrodes will be placed over the motor points of each of the above muscles. The EMG signals will be transmitted to the receiver unit (Noraxon Telemyo 8) and then fed into a computer for display and recording the data. Before beginning data collection on the experimental exercises, each subject will be asked to perform a maximal voluntary contraction (MVC) of each of the six muscles to be studied. The activity of the MVC will be assumed to a 100% EMG activity level distinct to each muscle and will allow the comparison of the muscle activity generated during the experimental trial. Incorporating this procedure allows the EMG data to be normalized for later analysis.

An electrogoniometer (Penny & Giles Model 180) will be used to measure the hip and knee range of motion during the experimental exercises. The two electrogoniometers used in this study, one for the hip joint and one for the knee joint, will be calibrated before running the subject trials to ensure the accuracy of measurement. For the hip joint, the electrogoniometer will be attached to the pelvis and thigh, underneath the subject’s clothing, using double sided-adhesive tape. The knee joint goniometer will be attached in the same manner to the thigh and leg above and below the knee joint respectively. This will allow the measurement of hip and knee flexion during the experimental exercises which will be used in later analysis of data.

Prior to running the experimental trials, the age, weight, and height of each subject will be recorded. The EMG activity and electrogoniometric data of the right lower extremity and back will be used for all subjects. Before beginning the experiment, each subject will be given a short training session on the correct use of the Plyo Press, correct squat lifting techniques, and the desired vertical jump technique to be used. Each subject will, as well, be given a short “warm-up” period on the Plyo Press to become familiar with the operation of the machine. Assistance (“spotters”) will be provided to each individual during their squat lift using free weights as a precautionary measure.

To begin the actual experiment, each subject will be fitted with the EMG electrodes and the electrogoniometers. The motor points of each of the six muscles to be studied will be determined and the skin over these points prepared for optimal contact with the EMG electrodes by cleansing with alcohol. The surface electrodes will then be filled with conductive gel and applied to the subject’s skin, over the motor point, with adhesive. A ground electrode will also be placed in the same manner over the tibial tubercle. The subject will then be asked to elicit a MVC of each of the monitored muscles, which will be recorded in the computer as a reference level of muscle activity.
weights equal to 80% of 1RM, 2) a Plyo Press leg press with weight equal to 80% of 1RM, 3) a vertical jump standing, and 4) a vertical jump maneuver in the Plyo Press (called a Plyojump). These trials may be performed in any order to incorporate randomization to limit misrepresentation via muscle fatigue. The subjects will be given a 3-5 minute rest period between trials, and a rest period upon completion of the 4 trials while the electrodes and electrogoniometers are removed.

Descriptive statistics describing the subjects anthropometric profiles will be provided. Statistical analysis will be performed on the integrated EMG activity during the 4 trials and will be compared with the MVC data as a percentage using normalized EMG. At this time it is anticipated that we will use analysis of variance (ANOVA) to measure the differences in EMG data collected in the 4 trials. The squat exercise, the Plyo Press exercise, and the two jump techniques will be compared with each other respectively. The electrogoniometry data will be analyzed and descriptive statistics and ANOVA procedures will be used to describe the changes that occurred in range of motion at the hip and knee joints during the individual trials.

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

The data produced by this study will be beneficial in providing support for the utilization of the Plyo Press in strength training as an excellent dynamic strengthening tool. At the present time, research on this machine is needed to help provide knowledge about its designed functions and promote its use in programs where safe and efficient strength training in incorporated. The results of this study will help determine the difference in the amount of stress placed on the lower back with the use of the Plyo Press which can then support the use of the Plyo Press in a wide range of strengthening and rehabilitation programs. This data will also provide a base of information to proceed with research studies to determine further benefits of the use of the Plyo Press on patient population.

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.)

The risks to the subjects involved in this experiment are anticipated to be minimal. The selection criteria that will be taken are designed to ensure that the lifts, techniques, and amounts of weight lifted by each participant is well within his individual limits and capabilities. Precautions will be taken via providing assistance ("spotters") of needed, and instruction on proper lifting and performance techniques to minimize risk for injury during the experimental procedures. Any risks of injury anticipated from participation in this study is no greater than the participation in each individual’s normal strengthening programs. The EMG and electrogoniometer equipment causes no discomfort to the patient, since they are both used only as monitoring devices. The subjects will be asked to wear gym shorts for the experiment, and every effort will be made to prevent any loss of dignity for the subject during the course of the experiment. It is anticipated that the experiment trials will take place at the Sports Acceleration Departments at the Medical Center Rehabilitation Hospital (MCRH) Grand Forks, ND, or at Red River Valley Sports Medicine, Fargo, ND where a Plyo Press machine is located.
5. CONSENT FORM: A copy of the CONSENT FORM to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no CONSENT FORM is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

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

The consent forms will be kept by Thomas Mohr in the Department of Physical Therapy, Room 149, Medical Science North for a period of two (2) years. A copy of the consent form is attached.

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

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

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

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

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

SIGNATURES:

[Signature]
Principal Investigator

DATE: 4/16/96

[Signature]
Project Director or Student Adviser

DATE: 

[Signature]
Training or Center Grant Director

DATE: 

(Revised 8/1992)
UNIVERSITY OF NORTH DAKOTA'S
INSTITUTIONAL REVIEW BOARD

DATE: April 16, 1996
PROJECT NUMBER IRB-9604-206

NAME: Thomas M. Mohr; Heidi C. Meyer DEPARTMENT/COLLEGE Physical Therapy

PROJECT TITLE: An Electromyographic Study of Back and Lower Extremity Muscles During a
Free Weight Squat and the Plyo Press Leg Press at 80% of 1 RM

The above referenced project was reviewed by a designated member for the University's Institutional
Review Board on April 22, 1996 and the following action was taken:

☑ Project approved. EXPEDITED REVIEW NO. 3. Next scheduled review is on April 1997.

☐ Project approved. EXEMPT CATEGORY NO. _______. No periodic review scheduled unless so stated in
REMARKS SECTION.

☐ Project approved PENDING receipt of corrections/additions in ORPD and approval by the IRB.
This study may NOT be started UNTIL IRB approval has been received. (See REMARKS SECTION for further
information.)

☐ Project approval deferred. This study may not be started until IRB approval has been received. (See
REMARKS SECTION for further information.)

☐ Project denied. (See REMARKS SECTION for further information.)

REMARKS: Any changes in protocol or adverse occurrences in the course of the research project must be
reported immediately to the IRB Chairman or ORPD.

cc: T. Mohr, Adviser
Dean, Medical School

Signature of Chairperson or designated IRB Member Date
UND's Institutional Review Board

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a
special assurance statement or a completed 596 Form may be required. Contact ORPD to obtain the
required documents. (7/93)
Information and Consent Form

Title: An electromyographic study of back and lower extremity muscle recruitment during a squat using free weights and the Plyo Press leg press

You are being invited to participate in a study conducted by Thomas Mohr, a Professor in the Physical Therapy Department at the University of North Dakota, and Heidi Meyer, a senior Physical Therapy student in the Physical Therapy program at the University of North Dakota. The purpose of this study is to compare the differences the in the muscle recruitment of muscles in your lower back and lower extremity when you perform a squat lift and a leg press on the Plyo Press machine. The Plyo Press was designed to allow strength training to occur without added stress to the low back or leg joints.

You were selected to participate in this study because you are:
1. male
2. 18-35 years old
3. not experiencing any hip, knee, or back injuries or problems (pathology)
4. currently participating in a weight training program one or more times per week
5. able to safely squat a weight equal to 80% of your 1 RM using the correct technique, procedure, and body awareness.
6. familiar with the Plyo Press machine and have used it in your weight training program at some time.

You will be asked to perform 2 different lifts and two jumps for the experimental trials. These procedures consist of 1) a squat lift with free weights equal to 80% of your 1 RM, 2) a Plyo Press leg press with weight equal to 80% of your 1 RM, 3) a standing vertical jump, and 4) a vertical jump technique in the Plyo Press (referred to as a Plyojump). You will be given a short instructional session and trial period to warm-up and familiarize yourself with the equipment you will be using. Assistance in the form of spotters will be available to you if needed throughout the testing procedures.

The study will take approximately one hour of your time. You will be asked to report to the Sports Acceleration Department at the Medical Center Rehabilitation Hospital (MCRH) in Grand Forks or at the Red River Valley Sports Facility in Fargo an assigned time. You will then be given time to change into proper clothing for the experiment (i.e. gym shorts and t-shirt). We will first record your age, weight, height, and gender. During the experimental procedures, we will be recording the amount of muscle activity that occurs in your low back and leg muscles and the amount of movement your knees and hips go through when you are performing the weight lifts and jumps.

The way we will record your level of muscle activity is through electromyography (EMG). We will be placing two electrodes on each of the six muscles we will be studying (a total of twelve) at points where the best EMG reading can be monitored. In order to locate the area on your muscle that will give the best EMG reading, we will use a small stimulator to electrically stimulate the muscles to contract. The stimulator will cause a mild tingling sensation. To place the electrodes on your skin, we will prepare the skin surface by rubbing it with alcohol and then attaching the electrodes to the skin with adhesive tabs. If necessary, we may need to remove leg hair with a razor in order to allow proper attachment of the electrodes. We will also attach a measuring device to the outside of your knee and hip with adhesive tape. This device is what measures how much movement occurs at the joint. None of these electrodes or devices will penetrate the skin, and they should cause no discomfort. These devices do not stimulate your skin or muscles, they simply record information from your muscles and joints.

For the actual experiment, you will be asked to give a maximal contraction of each of the muscles we will be monitoring. Then you will perform the two lifts and two jumps in a random order. You will have a 3-5 minute rest period between each of the experimental trials. We anticipate that the experimental session will last for about one hour total.
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 to you is minimal. The electrodes are measuring devices and should cause no discomfort at all, while the electrical stimulation used to find the electrode placement sites should cause only brief, minimal discomfort. The risks of injury to you in this study are no greater than during your normal strengthening program. Minor side effects you may experience include muscle soreness and fatigue which should resolve within a short time frame.

All information from this study that can be identified with you will be kept confidential and your name will not be used in any reports of the study. Any information obtained in connection to this study that can be identified with you will be disclosed only upon your permission. The data will be anonymously coded and will be identified by a number known only to the investigators. Your participation is entirely voluntary. You have the right to withdraw your consent and discontinue your involvement in this study at any time without prejudice to the future relations with the investigator or the faculty of the Physical Therapy Department of UND. If you decide to participate, you may discontinue participation at any time.

The investigators involved are available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions related to this study that you may have in the future. Questions may be asked any time by contacting Dr. Thomas Mohr at (701) 777-2831. A copy of this consent form will be provided for you.

In the event that this research activity results in a physical injury, medical treatment will be available, including first aid, emergency treatment, and follow up care as it is to a member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payer, if any (eg. health insurance, Medicare, etc.). In signing this form, you are agreeing that the University of North Dakota, the UND Physical Therapy Department, and the investigators of this study are not liable for any injury sustained during, or as a result of, this experiment.

All of my questions have been answered and I have been encouraged to ask any questions that I may have concerning this study now and in the future. My signature indicates that I, __________________________________________________________ have read all of the above and willingly agree to participate in this research study.

I have read all of the above and willingly agree to participate in this study as explained to me by __________________________________________________________

__________________________________________  ____________________________
Participant's signature                      Date

__________________________________________  ____________________________
Investigator's signature                    Date

__________________________________________  ____________________________
Witness                                     Date
REFERENCES


