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An Electromyographic Study of Back and Lower Extremity Muscle Activity during Plyopress Exercises, a Squat Lift, and a Vertical Jump

Melissa K. James

University of North Dakota

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AN ELECTROMYOGRAPHIC STUDY OF BACK AND LOWER EXTREMITY MUSCLE ACTIVITY DURING PLYOPRESS EXERCISES, A SQUAT LIFT, AND A VERTICAL JUMP

by

Melissa K. James
Bachelor of Science in Physical Therapy
University of North Dakota, 1995

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1996
This Independent Study, submitted by Melissa K. James 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**

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Date: 12-13-95
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ABSTRACT

The ongoing research in the evolution of athlete training continues to reveal new principles and training designs which strive to heighten athletic performance and maximize athletic ability. One example of the application of such research is the Plyo Press machine, a patented device used in the Frappier Acceleration Program for athletes. This device was specifically designed to combine strength training with plyometrics to enhance speed and dynamic muscle activity without the excessive low back stress of traditional training methods.

As the Plyo Press has been recently designed and incorporated into training programs, no research has yet been conducted on the machine to validate the claims made by the manufacturer. Therefore, an EMG analysis of selected back and lower extremity musculature was conducted in an attempt to provide information on the muscle activity and recruitment pattern elicited by the Plyo Press. The purpose of this study was to compare muscle activity levels during the Plyo Press exercises with traditional strength and power training exercises (i.e. a squat lift and a vertical jump), to determine effects on muscle activity regarding task experience, and to determine the resulting changes on muscle activity with usage of a pelvic stabilization belt.
Ten healthy male subjects, who met the selection criteria, were asked to participate in this study. These athletes were divided into two groups (Trained and Untrained) based on their familiarity with the Plyo Press. Each subject performed a total of four different test exercises. An analysis of the normalized EMG data was conducted using the myosoft software package.

The results of this study showed that the Plyo Press appeared to specifically recruit the vastus lateralis muscle during each of the test sessions: 1) leg press vs. squat, 2) plyojump vs. vertical jump, and 3) with and without a pelvic stabilization belt. The Plyo Press appears to offer the advantage of specifically training the vastus lateralis muscle while minimizing recruitment of other lower extremity and back muscles.
CHAPTER 1

INTRODUCTION

As a result of years of evolution in athlete training, competition rules, and equipment adaptations, athletes today are performing feats and achieving records unimaginable just 10 to 20 years ago. The ongoing search for training methods to improve performance in competition places continuous demands on researchers.

There are a number of different training methods and programs available to prepare an athlete for a wide variety of sports. Strength (the maximal ability to apply a resist force)\textsuperscript{1,2} can be improved by simply increasing the amount of force a muscle can produce. Power (the functional application of the product of strength and speed),\textsuperscript{1,2} on the other hand, can be improved in two ways: 1) by increasing strength, and 2) by decreasing the time required to produce the strength. The majority of sports involve explosive movements that are dynamic in nature. Such movements require a combination of strength and power. It is this power component of athletic fitness that has been suggested to be the most indicative of success in sports requiring extreme and rapid force productions.\textsuperscript{3} Thus it would seem reasonable that optimal training in such sports would require unique combinations of strength and power training.
In order to train for specificity in power and strength, and to maximize the resulting functional achievements, the use of several different drills to complete training of all of the components of a particular sport has been necessary. Traditional lower extremity strengthening exercises, such as the slow, controlled squat weight lifting exercise, often fail to functionally train the power component of muscle activity for the speeds required during sport performance. Therefore, although the squat exercise is an excellent activity for strength gains, training at various speeds of movement is normally limited and additional activities must be initiated to train for power.

In an attempt to combine strength gains with improved velocity of movement, plyometric exercises are often implemented into the overall training program. Plyometrics are dynamic exercises that utilize a rapid eccentric muscle stretch (activating the stretch-shortening cycle), to produce a powerful concentric contraction response of a muscle. For example, vertical jump training is a conventional plyometric training exercise that enhances power; but the ability of this single exercise to coincide strength increases to supplement that power in a functional way is questionable.

The difficulty with training simultaneously for power and strength is one of several reasons that the Plyo Press (Acceleration Products, Inc., Fargo, ND 58103) lower extremity training device was developed. The Plyo Press is a machine designed for the explicit combination of strength training and plyometrics for the lower extremity. It works through a leg press maneuver
(lowering and lifting a load to at least $90^\circ$ of knee flexion and back to a fully extended position) and a plyojump maneuver (a vertical jump maneuver against resistance while on the sled). The *Plyo Press* is advertised as being superior to other strengthening devices used by athletes (e.g., Cybex Eagle equipment, free weights) because it was designed to train using dynamic exercise to specifically build strength in ways that benefit speed and power. This characteristic is claimed to be unique to this piece of equipment. Quite frequently, traditional dynamic exercises, such as plyometrics, cause increased and unwanted stress on the lower back and leg joints. The *Plyo Press* attempts to eliminate such hazards by allowing the load to be controlled.

Specific features in the *Plyo Press* design, devised to decrease risk of injury and enhance appropriate specificity of training, include the use of cams, an inclined sled, an elongated sled track, and an inclined footplate. The equipment is set up with three cams, which manipulate the weight of the applied load. The manufacturer claims this cam design is engineered to be sensitive to the load moment changes occurring during rising exercises by altering the amount of load applied. The inclined sled supports the upper body. The angle of the sled lies at approximately $15^\circ$ from the horizontal. This allows redirection of the flexor loading moment of the knee, and the stress placed on the joints of the back, hip, and knee as compared to the conventional squat exercise.

The elongated sled track and inclined foot plate are particularly important in the dynamic exercises performed on the *Plyo Press*. The length of the sled
track is approximately 108 inches. This length allows the athlete to perform
plyometric jumps of great "height" in the device which a conventional leg press
machine would restrict. The manufacturer claims that this ability to safely
perform plyometric jumps with varying amounts of added weight incorporates
strength gains along with improvements in speed and power. The foot plate is
angled at approximately 15° from the vertical. This causes forced plantarflexion
to occur when the athlete's foot contacts the foot plate. This encourages knee
flexion when landing during jump maneuvers, thus protecting the knees from
harsh hyperextension forces.

These features would appear to give the Plyo Press capabilities that are
impossible in conventional lower extremity strengthening exercises, such as
squats, leg press devices like the hip sled, and floor plyometrics. The Plyo Press
also has the unique ability to exercise muscles with loads less than, or greater to,
athletes' body weights. Its primary goals are to: 1.) decrease low back stress,
and 2.) increase quadriiceps muscle function during plyometric exercises with a
carry-over to sport performance. It is for these functions that the Plyo Press
presents itself to be an effective training device.

A device that allows training with precise focus on target muscle groups,
while minimizing risks for injury, would prove to be very beneficial to the athletic
population. However, there has been no scientific investigation of the Plyo Press
to test the claims made by the manufacturer. The claim that the Plyo Press
machine might allow strength and power training of the lower extremities
superior to current training methods has not been tested. In order to validate the manufacturer’s claims, and promote the use of the Plyo Press as a training device, scientific investigation to explore the muscle activity and range of motion requirements of the device is necessary. Therefore, the purpose of this study was to provide a comparison of muscle activity in the back and lower extremities between the Plyo Press training device and traditional strength and plyometric training exercises.
CHAPTER 2

LITERATURE REVIEW

Electromyography

Electromyographic (EMG) analysis provides an inferential measure of the force developed by a muscle. Although muscle force generated can not be calculated directly from the EMG signals, increased EMG activity suggests increased muscle force production.\textsuperscript{8-12} That is, surface EMG signals supply an estimate of the excitatory input to a muscle by reflecting the number of motor units recruited and their discharge frequency.\textsuperscript{13} The relationship between integrated EMG and muscle force is thus generally linear.\textsuperscript{8-10} It has been shown that this assumption holds true regardless of the methodology employed, as it is effected more by physiological characteristics of the muscles (i.e. fiber composition).\textsuperscript{14}

Typical Muscle Activity

EMG activity in the back and thigh muscles has been explored extensively by researchers\textsuperscript{5,7,15-23} The gluteus maximus (GM), vastus lateralis (VL), biceps femoris (BF), and lumbar erector spinae (ES) muscles are involved in most lower extremity exercises.
The vastus lateralis has been shown to be a powerful extensor of the knee, and is active throughout knee extension.\textsuperscript{6,15,17} The greatest VL activity levels have been evoked by resisting (or weighting) knee extension when the hip is flexed,\textsuperscript{15} as occurs in the \textit{Plyo Press} activities. Basmajian and Deluca\textsuperscript{15} also determined that this muscle demonstrates greater activity during concentric versus eccentric contractions, revealing smaller levels of VL activity during the down phase of squatting, than during rising.

One of the primary activities that elicits GM muscle contraction is extension of the thigh at the hip joint,\textsuperscript{15} which occurs during the rising phase of the \textit{Plyo Press} exercises. Although the GM works during hip extension, the hamstrings usually initiate this movement, and the GM acts synergistically when a greater force is required.\textsuperscript{7,16,18-19} Because of this major hamstring recruitment, the GM activity would be expected to be relatively minor during the rising phase of the leg press or squat.\textsuperscript{7,15,18}

The ES muscles have been observed to be active during slow forward flexion of the vertebral column, as well as during back extension.\textsuperscript{7,15,20-21} Both of these movements occur during the squat exercise. Basmajian and Deluca\textsuperscript{15} suggest that complete relaxation and lower levels of contraction of the erector spinae muscles are the "ideal" rather than common place for normal bending movements. These muscles were shown to contract vigorously during coughing and straining, as occurs during weight lifting, even in the fully flexed trunk position. Important in the application of the \textit{Plyo Press}, EMG signals have been
observed to fall, along with levels of disc pressure, when the back of a seated subject is supported.\textsuperscript{15} During squat lifting, the ES muscles play a greater role than other trunk muscles in providing stability to the spine throughout the lift.\textsuperscript{8}

Overall, increased loads result in increased muscle EMG activity for all muscles discussed.\textsuperscript{15,22} Posture is also a major factor in ES activity levels especially (e.g. when lumbar lordosis is present).\textsuperscript{23}

**Specific features of the *Plyo Press* design**

The *Plyo Press* design was created with the intent to optimally enhance muscle function while decreasing joint stress via the arrangement and function of its specific features, the cam arrangement and the sled angle.

Studies have shown that the greatest hip extensor muscle moments are generated at 90\(^\circ\) of hip flexion (e.g. deep squat) and decrease markedly as the hip moves toward full extension (e.g. rising from a squat), regardless of the knee angle.\textsuperscript{7} At the same time, the lever arm of the quadriceps is most favorable when the hip is flexed, but the smallest muscle forces are exerted in this position.\textsuperscript{24-25} Instead, the maximum knee extensor moment thus increases with hip extension\textsuperscript{7,26} (as the hip moment decreases), occurring between 50-70\(^\circ\) knee flexion.\textsuperscript{24} Thus, in respect to a rising exercise, it would be expected that the hip extensor musculature would likely be responsible for the initial movements, while the quadriceps would likely become more dominant in the later phases of the lift.

Maximum joint loading forces also occur at different angles for both the hip and knee joints. Several studies agree that the initial knee joint loading
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moment force is higher at large knee angles and markedly decreases at smaller knee angles.\textsuperscript{5,24-25,27} The maximum hip loading moment occurs around 75° of hip flexion and, like the knee, decreases as the hip moves toward extension.\textsuperscript{7}

The cam arrangement allows the \textit{Plyo Press} to be sensitive to these high stress positions by altering the applied load. The cam arrangement supposedly allows for a 25% decrease in load at approximately 90° of hip and knee flexion, when the knee joint load moment is high and the quadriceps muscle moment is at its smallest.\textsuperscript{5,24-25} At this point the hip extensor force is at its highest and can balance out the lessened quadricep force.\textsuperscript{7,24-25} As the knee moves toward extension, in the rising phase of the exercise, the knee joint load moment decreases and the quadriceps muscle force moves toward maximum.\textsuperscript{5,24-25} Thus, to maximize muscle strengthening, the cam arrangement of the \textit{Plyo Press} is supposedly designed to provide 100% of the load lifted at approximately 45° of knee flexion. Finally, at full lower extremity extension, when joint loading factors are minimal, 125% of the load is believed to be provided as resistance by the \textit{Plyo Press} (particularly during dynamic exercises). For these characteristics, the manufacturer claims the \textit{Plyo Press} is able to enhance the ability of muscle force while synchronously being sensitive to patello-femoral joint reaction forces.\textsuperscript{4}

The incline of the \textit{Plyo Press} sled is also sensitive to muscle moments and loading forces of the lower back muscles. The maximum muscle moment of the lumbar ES is difficult to label with a specific degree angle because of the many vertebral joints the ES effects; but it has been determined that the peak
flexion-extension moment occurs at L₅-S₁ and increases with increasing loads during a squat lifting exercise with the back straight and the hips and knees bent. In several studies which examined ES activity and load moments during squat lifting, a greater loading moment occurs in the lumbar spine during the initial portions of the lift, due to the need to stabilize the pelvis, and overcome inertial forces to perform and complete the lift successfully. The ES muscle activity is important in counterbalancing forward bending movement in the lumbar spine, especially in the initial phases of the standing squat lift. Without this muscle counterbalance, the non-contractile elements of the lumbar spine would replace the muscles, setting the spine up for potentially damaging consequences to these structures. The support provided by the horizontally aligned sled of the Plyo Press eliminates the need for forward bending of the spine, thus decreasing the loading moment and the need for muscular stabilization.

During a standing squat exercise, the center of gravity of the weight of the body, plus any additional load, falls behind the knee, resulting in a knee flexor moment (or a tendency for the knee to rotate into flexion). At this point, there must be a net quadriceps muscle moment equal in magnitude to the flexor loading moment to counteract the knee flexion. Once the center of gravity and resultant reaction forces passes in front of the knee, the flexor loading moment reaches zero and changes to an extensor loading moment (causing the knee to extend). By placing the angle of the sled more horizontally, the Plyo Press
alters the crucial zero point and allows greater efficiency in quadricep training in particular.

**Similar training devices**

Although no previous study of the performance of the *Plyo Press* have been conducted, there are studies which investigated the hip and knee load moments and muscle activity during rising using a thigh exercising device which exhibits similar characteristics to the *Plyo Press*.\(^5\)\(^7\) Shared features between these two devices included: a fixed back support on a movable sled, a slightly inclined foot plate, and an ability to make changes in resistance by attaching or removing weights from the sled. Also, correct performance on both devices consists of moving the back support upward on the track while rising from squatting.\(^5\)\(^7\)

One of the parameters investigated for this device was the resulting muscle activity levels and loading moments observed when the back support was altered between 10-45° of backward inclination. Findings during the 45° inclined condition as compared to the 10° inclination included: 1) an increased flexor loading moment by approximately 10 Nm for the knee, and by 5 Nm for the hip, 2) the change of the point at which the knee flexor loading moment moves to an extensor loading moment occurred 10° earlier (at 40° of knee flexion rather than 30°), and 3) lower quadriceps activity, and slightly less hip extensor (GM and BF) activity occurred initially during the rising exercise but increased activity during the last phases.\(^5\)\(^7\) Due to the similarities in the design of these two
machines, it may be predicted that the Plyo Press would demonstrate similar findings.

Purpose

There is no direct evidence to substantiate the effects claimed by the manufacturer of the Plyo Press. Therefore, a scientific investigation of the muscle activity throughout the range of motion of the exercises specific to the Plyo Press is needed to support its claims. Thus, the purpose of this study was threefold: 1) to compare muscle activity in selected back (ES) and thigh (GM, VL, BF) musculature during two Plyo Press exercises with two traditional strength and power training methods (a standing free weight squat and a vertical jump), 2) to determine whether previous training on the Plyo Press had an effect on muscle recruitment during the exercises, and 3) to determine the timing of the recruitment of the selected muscles during the Plyo Press leg press and the squat exercise for a trained and an untrained subject. Two comparisons that are of particular pertinence to the Plyo Press are: 1) the levels of ES activity during the squat and leg press exercises, and 2) the peak VL levels during the plyojump and the vertical jump exercises.
CHAPTER 3

METHODS

Subjects.

Ten, healthy, male subjects 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 strength training program (independently or supervised) at least one or more times per week, and 3) be able to safely and appropriately squat free weights equivalent to body weight. The subjects were divided into two equal groups as a means of monitoring possible variations in results due to learning factors and task experience. The "Trained Group" consisted of five subjects who were familiar with the use of the Plyo Press leg press machine in their present training programs. The "Untrained Group" consisted of five subjects who were not familiar with the Plyo Press leg press machine.

Each subject was informed of the testing procedures and his rights as a participant in accordance with Institutional Review Board procedures at the University of North Dakota. Each subject signed an informed consent form prior to voluntary participation in the study (see appendix).
Table 1: Subject demographic characteristics.

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<tr>
<td><strong>Age (years)</strong></td>
<td>25</td>
<td>22 - 29</td>
<td>2.41</td>
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<tr>
<td><strong>Height (inches)</strong></td>
<td>72</td>
<td>67 - 75</td>
<td>2.68</td>
</tr>
<tr>
<td><strong>Weight (pounds)</strong></td>
<td>187</td>
<td>155 - 265</td>
<td>33.21</td>
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**Instrumentation.**

Electromyography (EMG) signals were used to determine the activity of the low back and leg muscles. A Noraxon Telemyo8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ, 85254) was used to collect the electromyographic 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 telemetried 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 analyze the digitized EMG signals in a variety of forms.

**Procedure**

Electromyographic activity was monitored in four selected muscles on the right side of the body: Erector Spinae (ES), Gluteus Maximus (GM), Vastus Lateralis (VL), and Biceps Femoris (BF). These muscles were chosen because
of their potential contributions to the performance of the Plyo Press leg press and plyojump exercises, as well as traditional squat lifts and vertical jump maneuvers.\textsuperscript{5,15-23}

Electromyographic activity was recorded via pre-gelled silver-silver chloride surface electrodes (Multi Bio-Sensors, El Paso, TX 79913). Electrode placement was set according to the motor points of the selected muscles, which were determined, with the use of a direct current surface stimulator (Low Volt Therapeutic Generator, Model SP2, Teca Corp., White Plains, NY), to be at the points in the muscles where the greatest amount of isolated muscle contraction was elicited.

To reduce skin impedance and ensure optimal contact with the electrodes, the skin over each electrode sight was rubbed with alcohol, and shaved of hair if needed, before application of the EMG surface electrodes as recommended by authors of prior EMG studies.\textsuperscript{15,32} Two surface electrodes were placed around one motor point of each individual muscle. The pairs of electrodes were applied in line with (parallel to) the direction of the selected muscle fibers at the determined motor points of the four muscles as recommended for optimal motor unit recording.\textsuperscript{32} Electrodes were secured in place with an adhesive backing. The interelectrode separation for each pair of active electrodes was set at approximately 1/2 inch, the recommended interval needed to maximize the EMG signal amplitude and minimize the amount of
volume-conducted activity from extraneous muscles.\textsuperscript{15,32} A common ground electrode for all of the electrodes was placed on the right tibial tubercle.

The axis of the electrogoniometer was placed at the level of the knee joint space on the lateral aspect of the right knee, using double sided adhesive tape. The proximal arm of the electrogoniometer was aligned with the longitudinal axis of the femur. The distal arm was aligned with the longitudinal axis of the tibia.

To record EMG and electrogoniometric activity, the EMG signals were transmitted from the surface electrodes and electrogoniometers 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.

To enable us to normalize the EMG activity during the testing activities, all subjects performed maximal voluntary isometric contractions (MVC) against manual resistance for each of the four muscles monitored. The methods and positions used to obtain the MVCs were according to a pilot study performed by Vakos, et al.,\textsuperscript{8} and by manual muscle testing techniques as described by Hoppenfield,\textsuperscript{33} with the exception of the VL. When testing this muscle in a position with the knee fully extended, as traditionally tested in manual muscle tests, it has been shown that the "screw home" extension mechanism of the knee aids the quadriceps in resisting the forced flexion and thus tests the ability of the stabilized, fully extended knee, to remain locked rather than the isolated force of the quadriceps muscles.\textsuperscript{24} Thus, to maximize the test of the force of the
quadriceps muscles, the knee was bent slightly to avoid the rotary locking mechanism.

The MVC data for each muscle was tested and recorded individually in the following manner: 1) ES: Each subject was prone on a platform with arms at his sides, muscles relaxed. On cue, each subject arched his back, lifting his chest off the platform while the tester applied manual resistance to the posterior shoulders, 2) GM: Each subject was prone on a platform with the right knee slightly bent, muscles relaxed. On cue, each subject extended his right hip while the tester applied manual resistance to the right posterior thigh, 3) VL: Each subject was seated with the left foot on the floor, the right knee passively flexed to 45° (held in this position by the tester), and muscles relaxed. On cue, each subject attempted to extend his right knee while the tester applied manual resistance to the anterior leg, 4) BF: Each subject was prone on a platform with the right knee passively flexed to 90° (held in position by the tester), muscles relaxed. On cue, each subject attempted to further flex the right knee against the manual resistance applied to the distal, posterior tibia.

The experimental testing activities consisted of four individual exercises which included: 1) a Plyo Press leg press, 2) a Plyojump (a vertical jump manuever in the Plyo Press leg press machine), 3) a standing squat using free weights secured on a shoulder bar, and 4) a standing vertical jump (Table 2). Each activity was performed with a weight equivalent to body weight added to
the lift, except for the vertical jump procedure which was performed with no added weight.

Table 2: Experimental exercises listed in the testing order.

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Exercise</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plyo Press leg press</td>
<td>with pelvic stabilization belt</td>
</tr>
<tr>
<td>2</td>
<td>Plyo Press leg press</td>
<td>without pelvic stabilization belt</td>
</tr>
<tr>
<td>3</td>
<td>Plyo Press plyojump</td>
<td>with pelvic stabilization belt</td>
</tr>
<tr>
<td>4</td>
<td>Plyo Press plyojump</td>
<td>without pelvic stabilization belt</td>
</tr>
<tr>
<td>5</td>
<td>Squat</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>6</td>
<td>Vertical Jump</td>
<td>------------------------------------------------</td>
</tr>
</tbody>
</table>

The starting position of each subject for EMG recording of the activities on the Plyo Press was with the feet shoulder width apart and centered on the platform, with the hips and knees fully extended. Correct body position in the machine was determined for each subject individually 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 was determined to be from 0° of knee extension, to approximately 90° of knee flexion, and back to 0° of knee extension. Each subject performed two trials of the leg press exercise, consisting of two repetitions each, for tests 1 and 2.
The *Plyo Press* plyojump procedure consisted of three plyometric jumps, one immediately following the other. The starting position of the plyojump was identical to that of the *Plyo Press* leg press (as described above). One repetition of the plyojump was determined to be from 1) $0^\circ$ of knee extension with both feet flat on the footplate, 2) through knee flexion before take-off, 3) through knee extension in take-off (no contact between the subjects' feet and the footplate), 4) through knee flexion in landing, 5) to $0^\circ$ of knee extension with bilateral foot contact with the footplate. Each subject performed two trials consisting of three repetitions of the plyojump each for tests 3 and 4.

The squat exercise was performed with the subjects standing, with their feet shoulder width apart, and their toes pointed straight anteriorly. The shoulder bar, with weights equivalent to each subject's body weight securely attached, was placed, and steadied, across the subjects posterior shoulders and neck by two of the testers. One repetition of the standing squat was determined to be from $0^\circ$ of knee extension, to at least $90^\circ$ of knee flexion (to the point at which the thigh was parallel to the floor), and back to $0^\circ$ of knee extension. Each subject performed two trials of two repetitions each, after which the shoulder bar and weights were lifted off of the subject's shoulders by two of the testers.

The vertical jump was performed from a standing position, with each subjects' feet shoulder width apart, with arms at the sides to use for balance and propulsion during the jump. One repetition of the vertical jump was determined to be from 1) $0^\circ$ of knee extension with both feet in contact with the ground, 2)
through knee flexion before take-off, 3) through knee extension following take-off (no contact between the subjects' feet and the ground), 4) through knee flexion following landing, and 5) back to $0^\circ$ of knee extension. Each subject performed two trials of two repetitions each of the vertical jump, with the second jump performed immediately following the first.

Subjects performed all procedures at their own rates. The subjects were given a 1 minute rest interval between trials and 3-5 minutes between the separate exercises.

**Data Analysis**

A comparison between two traditional methods used for strength and power training, squat lifting and a vertical jump, and the *Plyo Press* exercises was made by analyzing muscle activity: 1) during a *Plyo Press* leg press verses a standing squat with free weights, 2) during a *Plyo Press* plyojump verses a standing vertical jump, and 3) during the use of a pelvic stabilization belt verses no stabilization during the *Plyo Press* exercises. A final analysis was made of the timing of muscle activity in relation to knee flexion, to determine when during an exercise each muscle was active.

The results shown are based on the data from nine of the ten subjects. Data from one subject in the Trained Group was excluded due to incorrect recording of the MVC values for all four muscles. Therefore, the data represented includes four subjects in the Trained Group and five subjects in the Untrained Group.
One of the two trials performed for each test was selected to be used in data analysis. The repetition and cycle used for data analysis of each activity was as follows: 1) Tests 1, 2, and 5 (Plyo Press leg presses and the squat: Table 2); the second repetition, from 0° knee extension, to approximately 90° knee flexion, and returning to full extension, 2) Tests 3, 4, and 6 (plyojump and vertical jump: Table 2); from the peak knee flexion of the first repetition to peak knee flexion of the second repetition.

The EMG data for each of the four muscles studied were normalized for all subjects individually, using the method performed by Vakos, et al. First, a maximal EMG signal intensity, in mV, for was calculated for each subject from the activity during the maximal voluntary isometric contraction for each muscle. The MVC was defined as the mean of the 50 peak amplitudes during the middle 3 seconds of constant recorded contraction (not including ramping activity). Average muscle activity values, in mV, were then determined according to the cycle parameters for each muscle in each exercise. These averages were divided by the MVC value, and multiplied by 100 to obtain the %MVC for each subject. The individual EMG activity values for each subject were then calculated into %MVC averages for the two test groups. The range and standard deviation of all values were also determined.

Descriptions of common methods of analyzing muscle timing were difficult to obtain, even though several authors have conducted such studies. For this study, the timing of muscle activity during each exercise was determined by
comparing EMG muscle activity with the electrogoniometric readings. The threshold used for recognizing the onset of muscle activity was determined to be at 5% MVC for each muscle. Once the muscle activity reached 5% of the respective MVC, the muscle was considered "active" until the activity level dropped below the set value.
CHAPTER 4

RESULTS

Plyo Press leg press vs. squat.

The average muscle activity during the Plyo Press leg press and the squat exercises for the four muscles monitored is presented in Table 3. The data presented is from the test of the Plyo Press leg press with the pelvic stabilization belt in place.

The greatest amount of muscle activity for both the squat and leg press exercises occurs in the VL muscle for both groups (Figures 1 and 2). The average peak VL for both groups are 156.1% and 111.68% respectively. The erector spinae muscles for both groups display the next highest amount of muscle activity in both exercises, followed by the GM and BF muscles (which display less than 50% of the MVC average). The pattern of muscle activity (the relative levels of muscular recruitment) used in the leg press in all four muscles mirrors that elicited during the squat exercise (i.e. the VL consistently displayed the greatest activity levels, followed by the ES, GM, and BF respectively).

During the Plyo Press leg press, the VL is the only one of the four muscles monitored that elicits an activity level near, or above, the MVC (Figures 1 and 2). This average peak level is 76.1% for the Trained Group and 105.76%
for the Untrained Group. None of the remaining three muscles in either subject
group demonstrate activity above 25% MVC. In contrast, the squat exercise
elicits activity levels near, or above, 100% MVC for the ES muscles as well as
the VL.

In addition, the squat exercise elicits a greater amount of muscle activity
from all muscles involved than does the leg press activity (Figures 1-2). The VL
demonstrates 2.05 times greater activity during the squat than during the leg
press exercise for the Trained Group 1, but only 1.06 times greater activity for
the Untrained Group. The percent increase in activity from the leg press to the
squat for the remaining three muscles ranges from a 75-89% increase in activity
among both groups (Table 3).
Table 3: Average %MVC for the *Plyo Press* leg press (with stabilization belt) and the squat exercise.

<table>
<thead>
<tr>
<th>Musculature</th>
<th>Trained: Ave %MVC</th>
<th>Percent difference</th>
<th>Range</th>
<th>Std Dev</th>
<th>Untrained: Ave %MVC</th>
<th>Percent difference</th>
<th>Range</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Erector Spinae:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg press</td>
<td>22.88%</td>
<td>5.0-46.8</td>
<td>18.95</td>
<td></td>
<td>12.6%</td>
<td>5.8-19.7</td>
<td>6.18</td>
<td></td>
</tr>
<tr>
<td>Squat</td>
<td>90.55%</td>
<td>74.7% ↑</td>
<td>36-154</td>
<td>55.32</td>
<td>96.3%</td>
<td>86.9% ↑</td>
<td>41.9-182</td>
<td>54.85</td>
</tr>
<tr>
<td><strong>Gluteus Maximus:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg press</td>
<td>7.64%</td>
<td>.06-17.2</td>
<td>8.08</td>
<td></td>
<td>3.78%</td>
<td>1.5-9.1</td>
<td>3.07</td>
<td></td>
</tr>
<tr>
<td>Squat</td>
<td>56.2%</td>
<td>86.4% ↑</td>
<td>7.7-101.9</td>
<td>40.44</td>
<td>34.16%</td>
<td>88.9% ↑</td>
<td>8.9-62.6</td>
<td>21.79</td>
</tr>
<tr>
<td><strong>Vastus Lateralis:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg press</td>
<td>76.1%</td>
<td>29.6-114</td>
<td>34.83</td>
<td></td>
<td>105.76%</td>
<td>38.6-342.2</td>
<td>132.6</td>
<td>2</td>
</tr>
<tr>
<td>Squat</td>
<td>156.1%</td>
<td>51.2% ↑</td>
<td>56.1-214.9</td>
<td>69.35</td>
<td>111.68%</td>
<td>5.3% ↑</td>
<td>46.7-194.2</td>
<td>54.62</td>
</tr>
<tr>
<td><strong>Biceps Femoris:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg press</td>
<td>4.5%</td>
<td>0-6.8</td>
<td>3.06</td>
<td></td>
<td>7.23%</td>
<td>.84-14.2</td>
<td>5.61</td>
<td></td>
</tr>
<tr>
<td>Squat</td>
<td>28.33%</td>
<td>84.1% ↑</td>
<td>0-45.8</td>
<td>19.90</td>
<td>29.92%</td>
<td>75.8% ↑</td>
<td>1.7-48.5</td>
<td>20.51</td>
</tr>
</tbody>
</table>
Figure 1. EMG Activity for Muscle Groups (Trained Group)
Figure 2. Emg Activity for Muscle Groups (Untrained Group)

- Erector Spinae
- Gluteus Maximus
- Vastus Lateralis
- Biceps Femoris

Legend:
- Light gray: Leg Press
- Dark gray: Squat

% MVC

0 25 50 75 100 125 150

Muscle Groups:
- Erector Spinae
- Gluteus Maximus
- Vastus Lateralis
- Biceps Femoris
**Plyo Press Plyojump vs. the vertical jump.**

The data from the tests of the *Plyo Press* plyojump, utilizing the pelvic stabilization belt, was compared with the standing vertical jump muscle activity, a traditional power training exercise (Table 4).

Results revealed that both groups demonstrated a pattern of VL muscle activity that was 1.25-1.5 times greater during the plyojump as compared to the vertical jump (Figures 3-4). The average peak VL activity during the plyojump was 184.65% and 161.42% for the Trained and Untrained Groups respectively. During the plyojump, the prime muscle utilized by both groups was the VL muscle, followed by the ES, GM, and BF muscles, in that order (similar to the pattern seen in the leg press and squat). This pattern was also similar for the vertical jump, differing only in the Untrained Group where the ES activity was greater than the VL activity.

As in the leg press and squat exercises, the BF muscles in both groups participated in both jump exercises minimally with less than 50% of the MVC activity displayed (Figures 3-4). The GM was utilized to a greater extent than with the leg press and squat exercises, as indicated by activity levels greater than 50% MVC, with some values approaching the 100% MVC levels.

Figure 5 displays the average values for the Trained and Untrained groups combined during the leg press, squat, plyojump, and vertical jump exercises. Both the plyojump and vertical jump reveal an apparent increase in the "accessory" muscles (ES, GM, and BF) as compared to the squat exercise.
Table 4: Average %MVC activity for the *Plyo Press* plyojump, with a stabilization belt, and the standing vertical jump.

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Trained:</th>
<th></th>
<th></th>
<th></th>
<th>Untrained:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ave %MVC</td>
<td>Percent difference</td>
<td>Range</td>
<td>Std Dev</td>
<td>Ave %MVC</td>
<td>Percent difference</td>
<td>Range</td>
<td>Std Dev</td>
</tr>
<tr>
<td><strong>Erector Spinae:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plyojump</td>
<td>131.6%</td>
<td>37.9-182.8</td>
<td>65.72</td>
<td>129.76%</td>
<td>5.9-217.2</td>
<td>61.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vert. jump</td>
<td>132.4%</td>
<td>0.6%↑</td>
<td>62.2-270.9</td>
<td>95.27</td>
<td>182.8%</td>
<td>29.0%↑</td>
<td>100.8-384.2</td>
<td>116.22</td>
</tr>
<tr>
<td><strong>Gluteus Maximus:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plyojump</td>
<td>83.6%</td>
<td>.1-138.8</td>
<td>63.29</td>
<td>60.54%</td>
<td>27.4-127.1</td>
<td>42.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vert. jump</td>
<td>107.6%</td>
<td>22.3%↑</td>
<td>67.5-196.7</td>
<td>60.03</td>
<td>51.16%</td>
<td>18.3%↓</td>
<td>14.7-74.5</td>
<td>22.86</td>
</tr>
<tr>
<td><strong>Vastus Lateralis:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plyojump</td>
<td>184.65%</td>
<td>75.1-255.6</td>
<td>81.63</td>
<td>161.42%</td>
<td>86.9-409.5</td>
<td>139.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vert. jump</td>
<td>147.55%</td>
<td>25.1%↓</td>
<td>70.9-227.6</td>
<td>64.73</td>
<td>101.54%</td>
<td>59.0%↓</td>
<td>48-163.4</td>
<td>43.74</td>
</tr>
<tr>
<td><strong>Biceps Femoris:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plyojump</td>
<td>34.6%</td>
<td>3.9-91</td>
<td>38.53</td>
<td>38.46%</td>
<td>15.8-70.2</td>
<td>22.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vert. jump</td>
<td>47.23%</td>
<td>26.7%↑</td>
<td>5.1-92.9</td>
<td>35.93</td>
<td>46.9%</td>
<td>18.0%↑</td>
<td>13.9-105.7</td>
<td>35.53</td>
</tr>
</tbody>
</table>
Figure 3. Emg Activity for Muscle Groups (Trained Group)
Figure 4. EMG Activity for Muscle Groups (Untrained Group)

Erector Spinae
Gluteus Maximus
Vastus Lateralis
Biceps Femoris

Plyojump
Vertical Jump

% MVC
Figure 5. EMG Activity for four tests. (Average of Trained and Untrained)
Stabilization belt vs. no stabilization belt.

The comparison of EMG activity with and without the use of a pelvic stabilization belt during Plyo Press exercises is shown in Tables 6 and 7. Both exercises were performed under both conditions.

Data revealed that once again the pattern of muscle activity remains the same for both groups during the leg press, regardless of the use of pelvic stabilization (i.e. VL activity levels followed by ES, GM, and BF respectively) (Figures 6 and 7). The VL muscle was shown to be the primary muscle active during the leg press for both groups regardless of whether or not the stabilization belt was used. The remaining three muscles did not display activity levels above 25% MVC.

Although the relative patterns of activity levels during the leg press was the same between the two subject groups, there were some differences in the actual muscle activity levels (Figures 6 and 7). The Trained Group demonstrated increased activity levels in the VL, ES, and GM muscles while utilizing the stabilization belt. The greatest increase in activity occurred in the VL, with an increase nearly 1.5 times the activity occurring without the use of a belt. On the other hand, there was little change in the muscle activity levels in any of the four muscles in the Untrained Group, with and without the pelvic stabilization belt.

During the plyojump exercise, the two groups were similar in muscle activity levels and patterns, once again, for both testing conditions (Figures 8 and 9). The muscle activity pattern, from greatest to least activity levels, was
Table 5: Average %MVC activity for a *Plyo Press* Leg press with, and without, a pelvic stabilization belt.

<table>
<thead>
<tr>
<th> </th>
<th>Ave %MVC</th>
<th>Percent difference (with belt)</th>
<th>Range</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Belt</td>
<td>No Belt</td>
<td>Belt</td>
<td>No Belt</td>
</tr>
<tr>
<td><strong>Erector Spinae:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained</td>
<td>22.88%</td>
<td>10.5%</td>
<td>54.1% ↑</td>
<td>5.0-46.8</td>
</tr>
<tr>
<td>Untrained</td>
<td>12.6%</td>
<td>12.2%</td>
<td>3.2% ↑</td>
<td>5.8-19.7</td>
</tr>
<tr>
<td><strong>Gluteus Maximus:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained</td>
<td>7.64%</td>
<td>3.4%</td>
<td>55.5% ↑</td>
<td>.06-17.2</td>
</tr>
<tr>
<td>Untrained</td>
<td>3.78%</td>
<td>3.88%</td>
<td>2.6% ↓</td>
<td>1.5-9.1</td>
</tr>
<tr>
<td><strong>Vastus Lateralis:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained</td>
<td>76.1%</td>
<td>52.8%</td>
<td>30.6% ↑</td>
<td>29.6-114</td>
</tr>
<tr>
<td>Untrained</td>
<td>105.76%</td>
<td>102.3%</td>
<td>3.3% ↑</td>
<td>38.6-342.2</td>
</tr>
<tr>
<td><strong>Biceps Femoris:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained</td>
<td>4.5%</td>
<td>5.17%</td>
<td>14.9% ↓</td>
<td>0-6.8</td>
</tr>
<tr>
<td>Untrained</td>
<td>7.23%</td>
<td>7.17%</td>
<td>0.8% ↑</td>
<td>.84-14.2</td>
</tr>
</tbody>
</table>
Figure 6. EMG Activity For Muscle Groups (Trained Group: Leg Press)
Figure 7. EMG Activity for Muscle Groups (Untrained Group: Leg Press)
Table 6: Average %MVC activity for the plyojump with, and without, a pelvic stabilization belt.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Ave %MVC Belt</th>
<th>No Belt</th>
<th>Percent difference (with belt)</th>
<th>Range Belt</th>
<th>No Belt</th>
<th>Std Dev Belt</th>
<th>No Belt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Erector Spinae:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained</td>
<td>131.6%</td>
<td>126.85%</td>
<td>3.6% †</td>
<td>37.9-182.8</td>
<td>48.9-280.4</td>
<td>65.72</td>
<td>105.17</td>
</tr>
<tr>
<td>Untrained</td>
<td>129.76%</td>
<td>123%</td>
<td>5.2% †</td>
<td>59-217.2</td>
<td>76-204.1</td>
<td>61.76</td>
<td>54.48</td>
</tr>
<tr>
<td><strong>Gluteus Maximus:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained</td>
<td>83.6%</td>
<td>54.7%</td>
<td>34.6% †</td>
<td>.1-138.8</td>
<td>.1-91.3</td>
<td>63.29</td>
<td>39.74</td>
</tr>
<tr>
<td>Untrained</td>
<td>60.54%</td>
<td>49.4%</td>
<td>19.1% †</td>
<td>27.4-127.1</td>
<td>25.2-106.5</td>
<td>42.91</td>
<td>33.30</td>
</tr>
<tr>
<td><strong>Vastus Lateralis:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained</td>
<td>184.65%</td>
<td>169.25%</td>
<td>8.3% †</td>
<td>75.1-255.6</td>
<td>80.5-251.</td>
<td>81.63</td>
<td>72.64</td>
</tr>
<tr>
<td>Untrained</td>
<td>161.42%</td>
<td>153.76%</td>
<td>4.7% †</td>
<td>86.9-409.5</td>
<td>62.8-400.2</td>
<td>139.1</td>
<td>139</td>
</tr>
<tr>
<td><strong>Biceps Femoris:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trained</td>
<td>34.6%</td>
<td>24.18%</td>
<td>30.1% †</td>
<td>3.9-91</td>
<td>1-43.8</td>
<td>38.53</td>
<td>17.61</td>
</tr>
<tr>
<td>Untrained</td>
<td>38.46%</td>
<td>38.7%</td>
<td>0.6% †</td>
<td>15.8-70.2</td>
<td>23.3-54.3</td>
<td>22.20</td>
<td>13.17</td>
</tr>
</tbody>
</table>
Figure 8. EMG Activity for Muscle Groups (Trained Group: Plyojump)

- **Erector Spinae**
- **Gluteus Maximus**
- **Vastus Lateralis**
- **Biceps Femoris**

- **With Pelvic Belt**
- **Without Pelvic Belt**
Figure 9. EMG Activity for Muscle Groups (Untrained Group: Plyojump)

- **Erector Spinae**
- **Gluteus Maximus**
- **Vastus Lateralis**
- **Biceps Femoris**

- **With Pelvic Belt**
- **Without Pelvic Belt**
identical to that described above for the leg press (Figures 6 and 7). The differences in muscle activity with, and without, the pelvic stabilization belt during the plyojump were very similar to those of the leg press, as well. The most notable difference occurring when the belt was used, was a slight increase in the GM activity as compared to the exercise without the belt.

**Timing of muscle activity**

The timing of muscle activity (the cycle of when each muscle was active relative to range of motion) is represented by samples from two subjects (one trained and one untrained) in Figures 10 and 11. The actual integrated EMG recordings throughout the range of motion for the trained subject are also presented in Figure 12. (Note: Figures 10 and 11 represent the total time throughout the range of motion that each individual muscle is active according to the set threshold, while Figure 12 shows the level of activity.)

For the trained subject, all four muscles displayed EMG activity throughout the squat exercise (Figure 10). On the other hand, during the Plyo Press leg press only the VL and BF displayed constant activity, while the GM displayed no activity. During this exercise also, the ES activity occurred only during the greater ranges of hip and knee flexion (between approximately 45-90°).

The untrained subject demonstrated less constant threshold activity throughout both exercises than did the trained subject (Figure 11). During the squat exercise, the untrained subject exoked VL and BF activity throughout the
range of motion, but GM and ES threshold activity only after the initial portions of the exercise (starting at approximately 20-30° of initial knee flexion and continuing through the lift). The muscle activity during the leg press exercise for the untrained subject was similar to that of the trained subject in that there was constant VL activity throughout, while no GM activity was observed. This subject's BF and ES activity patterns were different, though, displaying activity during primarily the rising phases of the leg press (from approximately 75-90° of knee flexion to near full knee extension).
Figure 10. EMG activity in muscle groups during leg press and squatting activities in relation to range of motion. (Data taken from trained Subject no. 2)

Erector Spinae

Gluteus Maximus
No Gluteus Maximus activity during PlyoPress

Vastus Lateralis

Biceps Femoris

Data taken from trained Subject no. 2.
Figure 11. EMG activity in muscle groups during leg press and squatting activities in relation to range of motion. (Data taken from untrained Subject no. 7)

Erector Spinae

Gluteus Maximus

Vastus Lateralis

Biceps Femoris

No Gluteus Maximus activity during PlyoPress
Figure 7. IEMG During Leg Press
(Trained subject #2)
CHAPTER 5

DISCUSSION

EMG normalization.

To allow for comparison of EMG signal intensity levels between subjects and muscle groups, quantification of EMG activity was performed. Normalization of EMG signals from a maximal isometric contraction is a common procedure used in many studies.\textsuperscript{29} This method is based on the assumption that a maximal voluntary contraction elicits maximal firing levels of all motor units of a particular muscle. Problems with this assumption have been discussed by other authors\textsuperscript{41} and may include the fact that the ability to perform a true voluntary contraction of this sort may depend on previous muscle training as well as physical conditioning, posture, and body awareness.\textsuperscript{29} The advent of eccentric isokinetic dynamometry, as well, has provided contradicting results to the theory that human muscle has the greatest force producing potential in an isometric contraction.\textsuperscript{42} Often normalized values may be higher than MVC values due to the difficulty in the standardization of test contractions.\textsuperscript{5} This obstacle occurred during the present investigation, incurring a possible limitation to the study. Considering these inconsistencies, the use of EMG normalization in this study was utilized to give indications of the magnitude of activation rather than
absolute values of muscle activity. Data analysis was based on descriptive statistics rather than statistical, to avoid inappropriate conclusions which may have been altered by the limited number of subjects.

**Plyo Press leg press verses squat**

Analysis of EMG recordings in this study revealed increased amounts of muscle activity elicited from all four muscles (particularly in the ES) during the squat, as compared to the leg press Figures 1 and 2). One possible explanation for these increases may be that the muscles involved must engage in a supportive function as well as facilitate the kinematic movement of the lift. Studies have shown that a standing squat lift requires an average trunk flexion of approximately 64° to maintain balance and place muscles in their most effective and efficient positions to complete the lift. In the squat lift, not only are the ES muscles recruited to stabilize and protect the lumbar spine, trunk, and pelvis, but they are also required to assist in returning the trunk to an erect position during rising from the squat. Through their connections to the thoracolumbar fascia, the ES muscles may also have the potential to engage the hip extensor muscles to assist in trunk extension of this lift, resulting in an increase in GM and BF activity as compared to the *Plyo Press* leg press.

The additional support and positioning the *Plyo Press* offers by placing the supported trunk in a more horizontal position may alter the low back muscle activity for other reasons as well. In this position, the force of gravity acting to flex the spine is eliminated and no forward flexion of the trunk is required to
accomplish the activity. Thus, all of the rising and lowering motion can come from the hips, knees, and ankles. It is also possible that this allows the load to be transferred from the back to the thigh muscles, in turn producing a lower level of ES activity during the leg press exercise. These reasons may contribute to the greater amounts of muscle activity (Figures 1 and 2) and longer periods of activation (Figures 10 and 11) during the squat exercise as compared to the leg press.

In this study, decreased level of ES activity is being interpreted as an indication that the loads and stresses on the spine are decreased, as during the Plyo Press leg press. This is from a perspective focusing on the differences in trunk range of motion and posture between the squat and the leg press. Since there is significant trunk flexion occurring during the squat exercise, it would be expected that higher levels of ES activity would occur to return the trunk to neutral. On the other hand, since EMG levels and disc pressure has been observed to fall when the back of a subject is supported,\textsuperscript{15} the Plyo Press allows the leg press exercise to be performed without any trunk flexion, thus requiring less ES activity because no kinetic movement is occurring. There is also the assumption that in minimizing postural disturbance, the compressive loading on the spine should also be expected to be reduced.\textsuperscript{44} It should be noted however, that there are arguments that activity in the ES musculature is desired because ES tension reduces the strain on the tissues and non-contractile structures of the spine.\textsuperscript{23}
Although the Plyo Press leg press does not appear to elicit as much VL activity as does the squat lift, the majority of the total muscle activity occurring is seen in this muscle (Figures 1 and 2). The other three muscles appear to assist in only a minor portion of the lift (eliciting less than 25% of their MVC's). This specificity of muscle recruitment may indicate that the cam arrangement does indeed encourage a lifting strategy that enhances quadriceps function along with decreasing the role of the ES and stabilizing the spine and pelvis.

Another possibility for the dominant VL activity and general decrease in accessory muscle activity during the leg press might be the additional effects of antigravity lifting. In performing the squat lift, the subjects lifted not only the applied load (equal to body weight) in an antigravity manner, they also had to account for the total percent of their actual body weight (approximately 93%) that they moved against gravity in both the lifting and lowering phases of the lift. Because of the horizontally aligned positioning of the subject in the Plyo Press, the applied load was lifted against gravity, but the additional force needed to move the weight of the body was diminished.

The significant decrease in ES activity and dominant VL activity observed during the Plyo Press leg press is clinically important when considering the excessive loads typically applied during strength training. Most strengthening loads are typically greater than body weight and may reach up to 600 pounds or more. It appears that in the Plyo Press such extreme and heavy loading would not produce as much stress on the low back and other lower extremity joints as
would the squat lift. The exploration of the changes in EMG recordings with applied loads exceeding body weight would be very beneficial in future research and knowledge of the capabilities of the Plyo Press machine.

**Plyo Press plyojump verses vertical jump**

The most noticable difference seen between the two plyometric tests was in the level of VL activity. The data suggests that the VL activity was up to 1.5 times greater during the plyojump than the vertical jump (Figure 3 and 4). Possible explanations to this difference could be the function of the load altering cam design encouraging these effects, and the additional load applied in the Plyo Press (since the vertical jump was performed without any external load applied).

An apparently significant difference in relative activity levels of the primary stabilizers (ES, GM, and BF) was observed between the two plyometric activities as well (Figures 3 and 4). These muscle activity levels were lower during the plyojump than the vertical jump, which may be attributed to the major contribution of back and trunk support provided by the Plyo Press, as discussed previously.

It is also significant, that differences were seen between the plyometric jump activities and the strength exercises (Figure 5). My results indicate that the dominant action of the VL for both groups appears to be less during the plyometric jumps than that seen during the leg press. This may likely be due to the increased velocity of the plyometric exercises calling for increased
stabilization from all muscles involved. The main goal of plyometric training is to heighten the excitability of the nervous system to allow improvement in the ability of the neuromuscular system to react\textsuperscript{2}. The plyojump and vertical jump exercises both incorporate principles of plyometrics such as quick stretch, immediate rebounds, and multiple repetitions. Plyometric maneuvers such as these are performed at higher velocities than typical strengthening exercises. Thus, they require preparatory responses to the sudden loads that are transmitted to the lower extremity and lumbar regions. These responses can include muscle tensioning, co-activation, and postural changes which function to "take up the slack" and enable the system to produce a quicker response\textsuperscript{44}. Thus, higher levels of all muscles would be reasonably expected in the plyojump and vertical jump.

The implementation of such preparatory actions may also explain the apparently higher levels of activity in the ES and GM, muscles seen in both the plyojump and vertical jump, as compared to the squat exercise (Figure 5). It is reasonable to believe that this is due to the need for greater muscular stabilization during the sudden loading occurring when landing, as well as the increased concentric muscle activity (especially in the VL) from the activation of the plyometric stretch-shortening cycle before take-off. Studies have consistently shown that EMG activity is higher during concentric contractions than eccentric contractions of a given resistance load.\textsuperscript{3,15,45}
It is possible that the differences in velocity between the plyometric exercises and the slower strengthening exercises may have played a greater role in the differences seen in activity levels than explained here. This could not be determined directly from the experimental procedures we conducted, thus posing limits on the study. Possibilities for future investigations would include the utilization of objective measures of velocity (eg. metronome, video motion analysis).

**Trained verses untrained effects**

The *pattern* of muscle recruitment, from greatest to least activity, was similar between the Trained and Untrained subject groups in all of the exercises. The most obvious differences occurred in the relative levels of muscular activity. Higher levels of activity in the VL muscle were observed during the squat exercise for the Trained Group, which may have occurred partially due to the familiarity of the task and specificity of training (Figures 1 and 2). It has been determined that experience plays a factor in the development of motor control and expectancy development. Because the Trained Group regularly incorporated the *Plyo Press* leg press exercise into their training program, it would be expected that they may have achieved an efficient strategy in muscle recruitment and motor planning, as well as possible improved velocities, for this particular exercise. It is expected that this skill might then carried over to the squat exercise because of its similarities with the performance of leg press maneuver.
Contrastingly, the Untrained Group appeared to achieve a higher peak level of EMG activity in the VL muscle during the *Plyo Press* leg press than did the Trained Group (Figures 1 and 2). This may be associated to a greater extent with the additional support and stabilization provided by this machine, rather than the specificity of training for this subject group. The provision of these components by the machine appears to decrease the need for high levels of activity in the back and pelvic stabilization musculature and allow the subjects to focus more energy toward the desired kinetic movement of completing the lift. Such a drastic change in additional support would likely produce a dramatic result for an individual who is familiar with training without that support--as seen here.

The most notable difference between the two subject groups in the jump maneuvers was the characteristics of the ES and GM activity (Figures 3 and 4). For both the plyojump and the vertical jump, data for the Untrained Group suggests a high level of ES activity while the GM remains quite low, while the Trained Group on the other hand, reveals a more balanced increase in both the ES and GM activity levels. This might also be explained by the familiarity of the exercise and the resulting muscle strategies the Trained Group has developed. Not only might prior training on the *Plyo Press* effect the results, but the previous inclusion of various plyometric exercises in a training program might alter the results. It could not be determined how much this factor may have influenced the findings of both groups, since questioning about the types of prior subject
training was not conducted. It has been shown that task experience can effect how motor strategies reduce spinal compression forces during loading. The familiarity with the preparatory response to sudden loading allows a greater ability to cope and respond in an efficient manner. Thus, it could be possible that the trained subjects employ a muscle strategy that utilizes the pelvic stabilizers (GM and BF) to assist the ES muscles to a greater extent in maintaining a functional and efficient body position. From my data, it appears that the Untrained Group, on the other hand, may be relying more heavily on the back muscles (ES) to stabilize the lower body than the Trained subjects.

Velocity is a key component of plyometrics, thus partially accounting for the differences between the jumps and the strengthening exercises discussed here. By definition, velocity is the force divided by the distance covered. Since the distance the load is moved in both exercises isn’t expected to change a significant amount, a greater amount of force would be the primary factor of the increased velocity in this case. Therefore, the higher levels of activity (presumable meaning a higher level of muscular force) in all muscles for both groups during the jumps is thought to be a result of the more dynamic nature of these exercises as compared to the slower leg press and squat exercises. Because this investigation did not include objective measurements of velocity, these assumptions cannot be directly predicted from the data, thus limiting the study. Future investigations considering the effects of velocity components on
activity performance and EMG recordings for the Plyo Press would be clinically beneficial.

**Stabilization belt verses no stabilization belt**

The use of a pelvic stabilization belt appeared to have no effect on the pattern of muscle activity for either the leg press or the plyojump (Figures 6-9). There was, however, slight increases in muscle activity observed during the leg press with the use of the stabilization belt for the Trained Group (Figure 6). It is believed that task experience of these subjects once again plays a primary role in this finding. Since the muscle strategy assumed to be utilized by the trained group already focused on a more efficient way to stabilize the spine and pelvis to allow greater VL concentration, the addition of a pelvic belt would simply act as a security measure and increase the stabilization provided. This would then allow the subjects to focus even greater amounts of energy on the speed and power of exercise (psychologically and physically). The same effects were not seen for the Untrained Group because of the possible inefficiency of their lifting strategies for the Plyo Press exercises, as explained previously (Figure 7). Under this assumption, the neuromuscular system of these subjects would appear to be less sensitive to the additional assistance offered by the belt.

The use of the pelvic stabilization belt during the plyojump revealed only slight changes in activity levels (Figures 8 and 9). The greatest increases occurred in both groups for the GM muscle. This may have been due to the ability of the pelvic belt to stabilize the pelvis enough during the dynamic
movements to allow the GM to recruit more of its muscle fibers to contract to facilitate the lift without altering the altering the alignment of the pelvis and spine and diminishing the mechanical advantage of the ES.

Overall, the use of the pelvic stabilization belt appears to be a safety advantage during the leg press, and might be encouraged during the plyojump. Although, during this study, there appeared to be no increase in safety to the low back with the use of the stabilization belt, higher levels of loading may warrant a different response that needs to be investigated. All subjects in this study were carefully directed and supervised during performance, diminishing the possibilities for injury; but I would recommend the use of the pelvic belt as a precautionary measure during excessive loading and dynamic training.

**EMG activity in muscle groups**

The activity patterns seen for both subjects support the assumptions proposed throughout this discussion, that there are different motor planning and muscle recruitment strategies being utilized by subjects at different levels of training. Both subjects displayed an absence of, or minimal use of, GM and ES muscles throughout the *Plyo Press* leg press activity, while the VL was continuously active. (Presumably due to the target VL enhancement of the *Plyo Press*).

The continuous EMG activity for nearly all of the muscles during the squat lift for the trained subject, while less activity was noted early on in the lift for ES and GM for the untrained subject follows the assumption made earlier, that due
to the greater training skill of the Trained Subject and his ability to perform the exercise with more speed, control, and power, there is more muscle activity seen. The untrained subject appeared to utilize muscle activity in the supplemental muscles only when needed for stabilization and control.

The absence of GM activity for both subjects during the Plyo Press leg press, while the BF muscles remained active throughout the lift might suggest that the hamstring muscles were initiating hip extension and not enough force was needed at the loads used in this study to facilitate activity in the GM as mentioned previously.7,16,18-19
CHAPTER 6

CONCLUSIONS

In summary, these findings may provide some guide for clinical practice and utilization of the Plyo Press:

1. The Plyo Press leg press employs a lifting strategy which elicits safe and efficient VL strengthening with minimal co-contraction of other lower extremity muscles.

2. The Plyo Press encourages a significantly lower level of lumbar ES activity and low back stress through the mechanical advantages implemented by its design.

3. The plyojump elicits up to 1.5 times greater VL activity than does the traditional vertical jump maneuver.

4. The trained group demonstrated more efficient muscle strategies during exercises on the Plyo Press, which carried over to the squat and vertical jump exercises.

5. The strategies developed by the trained group required less ES activity for stabilization purposes, and greater emphasis on VL activity in all exercises.

6. There were no significant changes in muscle activity in the untrained group when the pelvic stabilization belt was not utilized, while the trained group
demonstrated an increased efficiency in lifting strategy utilizing the VL during the leg press exercise.

7. EMG muscle activity in muscle groups of a trained subject reveals that all four muscles are active nearly throughout the entire portion of the squat lift, while the only muscle active throughout the leg press was the VL. Lessened activity was observed in the ES and no activity was seen the GM muscles.

Traditionally, the squat exercise has been utilized in training to increase leg strength. The large amount of ES activity found in this study may present concerns when using this strengthening method for young athletes or athletes with low back pathologies. Results of this study support the use of the Plyo Press leg press machine in place of the traditional squat exercise. The Plyo Press appears to target the same muscle groups with a similar pattern of activity as does the traditional squat exercise, but with less activity of the ES. The reduced activity of the ES should translate into less stress on the lumbar spine. The reduced stress on the lumbar spine would be of benefit to individuals with spinal pathologies. Therefore, we propose that through its design, the Plyo Press encourages a body position and a muscle recruitment strategy that may allow the majority of muscle function to be focused on the task itself (utilizing VL activity to complete leg extension during rising) rather than dividing the total motor recruitment between supportive and dynamic roles.
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 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 machine, and 2) a vertical jump versus a plyojump in the Plyo Press machine. 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 his body weight using free weight. The subjects will be divided into two groups: 1) ten individuals who are currently on a strength training program that utilizes the Plyo Press regularly, and 2) ten individuals who train regularly but are not familiar with the Plyo Press. Each subject will perform four exercises and two jump procedures. The exercises will include a squat: 1) with free weights and 2) without weights; and a Plyo Press leg press 3) with body weight and 4) without weights. The jump procedures will consist of two vertical jump maneuvers, one standing, and one in the Plyo Press machine. The electromyographic (EMG) activity will be recorded for various lower back and thigh...
muscles and goniometric measurements will be taken at the hip and the 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 to 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 19-30 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 equivalent to body weight. The subjects will be recruited as volunteer subjects. To monitor possible variations in results due to learning factors, the subjects will be divided into two groups. Group 1 will consist of 10 subjects who are familiar with the use of the Plyo Press machine in their present training program. Group 2 will consist of 10 subjects who are not familiar with the Plyo Press machine.

METHOD:

We will measure the electromyographic (EMG) activity of four 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, and 4) vastus lateralis. 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 of 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 four muscles to be studied. The activity of the MVC will be assumed to be 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 four 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.

The actual experiment will consist of 4 squat lifts and two jumps. Each subject will perform: 1) a squat with free weights equal to his body weight, 2) a squat without free weights, 3) a Plyo Press leg press with weight equal to his body weight, 4) a Plyo Press leg press without weight, 5) a vertical jump standing, and 6) 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 6 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 6 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 6 trials. The two squat exercises, the two Plyo Press exercises, and the two vertical 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 is incorporated. The results off this study will help to 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 anticipate to be minimal. The selected criteria that will be taken are designed to ensure that the lifts, techniques, and amounts of weight lifted by each participant is within his individual limits and capabilities. Precautions will be taken via providing assistance ("spotters") if needed, and instruction on proper lifting and performance techniques to
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") if needed, and instruction on proper lifting and performance techniques to minimize risk for injury during the experimental procedures. Any risk 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 subject 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 experimental trials will take place at the Sports Acceleration Department at the Medical Center Rehabilitation Hospital (MCRH) where the 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.

5. 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: __________________________

DATE: __________________________

DATE: __________________________

Project Director or Student Adviser

DATE: __________________________

DATE: __________________________

DATE: __________________________

Training or Center Grant Director

DATE: __________________________

DATE: __________________________

DATE: __________________________
DATE: March 23, 1995 PROJECT NUMBER IRB-9503-233

NAME: Thomas M. Mohr; Melissa Temme James DEPARTMENT/COLLEGE Physical Therapy

PROJECT TITLE: An Electromyographic Study of Back and Lower Extremity Muscle Recruitment During a Squat Using Free Weights and the Pylo Press Leg Pre:

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on March 24, 1995 and the following action was taken:

☐ Project approved. EXPEDITED REVIEW NO. 3.
Next scheduled review is on March 1996.

☐ 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
REFERENCES


15. Basmajian, JV; Deluca, CJ. Muscles Alive; Their functions revealed by electromyography. 5th Ed. Williams & Wilkins, Baltimore, MD. 1985;22-23,45.


27. Lindahl, O; Movin, A; Ringquist, I: Knee extension measurement of the isometric force in different positions of the knee joint. Acta Orthop Scand.


