Electromyographic and Motion Analysis of the Trunk and Lower Extremity Muscle Recruitment Comparing a Maximal Voluntary Contraction to the Plyo Press and Agaton Max Series Leg Press

Lee Nagle  
*University of North Dakota*

Thayne Bosh  
*University of North Dakota*

Tonya Kunze  
*University of North Dakota*

Kelly Jorschumb  
*University of North Dakota*

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ELECTROMYOGRAPHIC AND MOTION ANALYSIS OF THE TRUNK AND LOWER EXTREMITY MUSCLE RECRUITMENT COMPARING A MAXIMAL VOLUNTARY CONTRACTION TO THE PLYO PRESS AND AGATON MAX SERIES LEG PRESS

by

Lee Nagle, Thayne Bosh, Tonya Kunze, Kelly Jorschumb
Bachelor of Science in Physical Therapy
University of North Dakota, 2002

A Scholarly Project
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
Masters of Physical Therapy

Grand Forks, North Dakota
May
2003
This Scholarly Project, submitted by Lee Nagle, Thayne Bosh, Tonya Kunze, and Kelly Jorschumb 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, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title  Electromyographic and Motion Analysis of the Trunk and Lower Extremity Muscle Recruitment Comparing a Maximal Voluntary Contraction to the Plyo Press and Agaton Max Series Leg Press

Department  Physical Therapy

Degree  Master of Physical Therapy

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Date  12/18/02
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We would like to thank John Frappier of Sports Acceleration in Fargo, ND for the opportunity to work with him at his facility as well as all of his help on this project.

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Lastly, we would like to thank our parents for their love and support throughout life and school as they have always stood by us. Thank You.
ABSTRACT

Numerous studies have been done on the Plyo Press, with focus on the concentric phase of the exercise. However, for athletes eccentric training has always been a topic of interest. Most leg press machines have a concentric and an eccentric phase involved with the exercise. However, during the eccentric phase of the leg press the muscles are underloaded because of the force-velocity relationship of the human skeletal muscle and the fact that eccentric contractions require fewer motor units for the same force and workload. This means that the leg press exercise is limited by the concentric phase. A new machine called the Agaton Max Series Leg Press takes this into consideration by being able to overload the eccentric phase of the exercise. The purpose of this study was to study the muscle activity in the back and lower extremities during both a jump on the Plyo Press and a leg press on the Agaton Max Series Leg Press. 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 Jump compared to the Agaton.

Thirteen healthy male subjects performed an exercise at 100% of their body weight on the Plyo Press, which was used as the dynamic baseline. The subjects performed three repetitions of a Plyo Jump and a leg press on the Agaton, both at 80% of their 1 RM. In addition, the eccentric phase of the Agaton was loaded at 200% of the concentric phase. These results were then analyzed using normalized EMG and motion analysis, and then compared using statistical analysis.
The results of this study showed a significant difference in EMG activity on the Plyo Jump as compared to the Agaton. The results also showed a significant difference in EMG activity between the concentric and eccentric phases on the Agaton, with the concentric phase producing more EMG activity. The results appeared to show advantages of training on the Plyo Jump and the Agaton, specifically incorporating eccentric muscle contractions.
CHAPTER I

INTRODUCTION

The demand on athletes to perform at high levels of competition no matter what level they participate is increasing dramatically. The use of eccentric muscle contractions to promote strength gains that carry-over to athletic activity is gaining in popularity. Therefore, research on appropriate training programs including eccentrics is needed to utilize its benefits for athletes.

There are a wide variety of different training methods available to better prepare athletes for athletic competition. The problem posed to clinicians is deciphering which training methods are best used to supplement each athlete’s own athletic ability. Most training methods incorporate some form of strengthening exercise along with functional movements. When discussing strengthening principles it is important to know that overall muscle strength and adaptation can be improved in three ways: 1) increase the load or resistance on a muscle, 2) increase the number of repetitions performed by the muscle, or 3) increase the speed of the muscle’s action. In order for strength to develop, muscular overload must be achieved over a minimum threshold level to induce a training response. This overload occurs between 60-70% of an individual’s one repetition maximum (1-RM).

To achieve overload of a muscle a number of different types of contractions can be used. Concentric muscle contractions occur in dynamic activities where muscles shorten and produce tension through the range of motion. Eccentric contraction occurs
when external resistance exceeds muscle force, and the muscle lengthens while tension develops. The third type of muscle contraction is isometric. Isometric (static) contraction occurs when a muscle attempts to shorten but cannot overcome the external resistance. All three types of muscle contractions can be used to increase an athlete's strength (the maximal ability to apply and resist force). Concentric and eccentric can also be used to increase muscle power (the functional application of the product of strength and speed). Strength and power are required in sports that involve explosive movements that are dynamic in nature. It is reasonable that training for such sports would require some balance of strength and power training.

Training programs to increase strength and power generally include combinations of eccentric and concentric contraction. On first appearance, these two types of muscle actions seem like they are a reversal of each other. However, on a physiologic basis they have some differences. Eccentric action is able to produce force or torque much greater than that of concentric action, and is known as the Elftman proposal.\textsuperscript{1-3} Research has shown that eccentric muscle action is able to generate from 112\% to 300\% the torque produced by the same muscle concentrically.\textsuperscript{2} Eccentric contractions produce increased force as the velocity of the muscle action increases, while the exact opposite occurs during concentric activity. One explanation for the eccentric contractions ability to produce greater force during activity involves the shorter time lapse between biochemical response and actual onset of muscle tension as compared to concentric contractions. Another reason is that noncontractile tissue adds to the force generation of the contractile component of muscle in eccentric activity. The opposite occurs during concentric...
contraction. As muscles concentrically contract the noncontractile elements contribute progressively less tension.

When comparing the benefits of concentric versus eccentric muscle contractions used as training methods, it is important to include in the discussion the different types of muscle fibers that are recruited during these activities. High load, high velocity contractions tend to recruit Type II (fast-twitch) muscle fibers, whereas low load, low velocity contractions favor recruitment of Type I (slow-twitch) fibers. For strength and power sports such as football, hockey, and volleyball, Type II recruitment during training is essential. However, Type II fibers are harder to recruit and usually occur only with concentric or isometric work during intense effort. Eccentric action recruits fast-twitch fibers predominantly because of the faster relaxation times secondary to a decreased biochemical delay as compared to concentric action.

Eccentric contractions require less energy and lower oxygen consumption. This advantage of eccentrics allows maximal effects of muscle training with the least amount of energy consumed. Differences in the amount of muscle activity required for a contraction can be shown with electromyography (EMG). To produce more force, concentric contractions require the recruitment of more muscle fibers. The increased recruitment causes the muscle to have an increase in electrical activity. Eccentric contraction produces more force with less energy and less muscle fiber recruitment and thus, shows less EMG activity than concentric contractions.

Delayed Onset Muscle Soreness (DOMS) has been associated with eccentric exercise. Albert suggests that it is due to the predominant recruitment of Type II fibers during eccentric activity because these fibers are intrinsically more susceptible to damage.
and are less often trained than Type I fibers. Concentric training only recruits Type II fibers with large amounts of effort. Conversely, eccentric contractions alter the recruitment order by bringing in more Type II fibers to produce the contraction.

To optimize the effects of both concentric and eccentric contractions, plyometric training is often used. Plyometric training movements make use of the stretch-shortening cycle. When stretching of a muscle occurs rapidly, stored elastic energy in muscle fibers during eccentric action produces a greater force in the early phase of concentric contraction. The eccentric component leads to greater mechanical efficiency and by combining the two, the work performed by the muscle is maximized.

The Plyo Press (Acceleration Products, Inc., Fargo, ND 58103) was developed to utilize the stretch-shortening cycle during training. Performing a Plyo Jump on the machine combines power and plyometrics in a dynamic activity to enhance speed and power of the lower extremity muscles. It incorporates the use of cams, inclined sled, elongated sled track, and an inclined footplate to decrease the risk of musculoskeletal injury while increasing strength. These features allow loads greater than an athlete’s body weight to be applied while performing a dynamic jumping activity while decreasing low back stress and increasing quadriceps function. The Plyo Press is designed to carry-over as much muscle memory and performance as possible to the athletic setting.

The Agaton Max Series Leg Press (Agaton Fitness, Inc., Moorhead, Mn 56560) was designed to maximize eccentric training. It uses a pneumatic cylinder driven by compressed air to add resistance during the eccentric phase of a leg press activity. Loads greater than an individual’s 1-RM can be performed during the eccentric phase of a leg press and a different load can be applied during the concentric phase of the leg press. For
example, if an athlete completes a concentric leg press with 100lbs. of weight, the machine can automatically apply a resistance of 200lbs. of weight during the eccentric phase. Use of the *Agaton Max Series Leg Press* for leg press activities has been shown to greatly increase the 1-RM of athletes in relatively short training periods.⁴

The *Agaton Max Series Leg Press* and the *Plyo Jump* have both been shown to increase strength and power in athletes that have trained with them.⁴,⁵ The purpose of this study was to provide a comparison of muscle activity in the back and lower extremities between a *Plyo Jump* and the *Agaton Max Series Leg Press*. The *Plyo Jump* has already been researched using EMG to provide an analysis of muscle activity. However, the significance of this study was to provide research to compare the EMG activity during the concentric and eccentric phases of an activity done on the *Agaton Max Series Leg Press*.

**Research Questions**

1. Is EMG activity during concentric contraction on the *Agaton Max Series Leg Press* similar to that of the EMG activity during a *Plyo Jump*?

2. Is EMG activity during concentric contraction similar to that of an eccentric contraction on the *Agaton Max Series Leg Press*?

**Null Hypotheses**

1. There is no significant difference between EMG activity during a concentric contraction on the *Agaton Max Series Leg Press* and the EMG activity during a *Plyo Jump*.

2. There is no significant difference between EMG activity during concentric and eccentric phases on the *Agaton Max Series Leg Press*. 
Alternate Hypotheses

1. There is a significant difference between EMG activity during a concentric contraction on the Agaton Max Series Leg Press and the EMG activity during a Plyo Press jump.

2. There is a significant difference between EMG activity during concentric and eccentric phases of the Agaton Max Series Leg Press.
CHAPTER II
LITERATURE REVIEW

Eccentric Training vs. Concentric Training

Eccentric muscle contractions are more efficient than concentric muscle contractions.\textsuperscript{2,6,8,10,12} This means eccentric contractions can produce higher forces with less oxygen consumption, carbon dioxide production, energy expenditure, and fewer motor units compared to concentric contractions with the same amount of workload and force. In addition, increased eccentric strength can improve a muscle's ability to withstand force and strain without failing.\textsuperscript{10} Researchers have attempted to quantify and develop specific eccentric training protocols, but have often been limited by improper resistance methods that have caused delayed-onset muscle soreness (DOMS).

Delayed onset muscle soreness (DOMS) is a form of muscle tissue damage that affects the entire functional muscle unit, and it is most likely due to structural and biomechanical changes that occur with eccentric exercise.\textsuperscript{11} Mechanical forces associated with an intense eccentric exercise bout may damage muscle proteins and connective tissue, leading to edema and an inflammatory reaction that causes secondary biochemical damage. It presents as dull, aching pain that develops 24 to 48 hours after an unaccustomed exercise. This pain typically peaks between 24 and 72 hours post-exercise when the muscles are tender and swollen. The formation of protective proteins such as desmin or thin filament during healing may be responsible for the attenuation of DOMS.
after the second bout of exercise. Collagen deposition and repair of the sacroplasmic reticulum and sarcolema would also provide further resistance to damage. The severity and distribution of the DOMS is dependent on the intensity, duration, and type of exercise performed. DOMS is primarily associated with eccentric exercise or passive lengthening of a contracted muscle.

Albert lists five theories that attempt to explain the etiology and process of DOMS from various authors. These include: lactic acid theory, torn tissue theory, tonic muscle spasms, connective tissue damage, and the tissue fluid theory.

Clearly et al. studied subjects performing exercise bouts of eccentric contractions of wrist extensor muscles with an isokinetic dynamometer and used a visual analog scale (VAS) to determine the subjects level of soreness and a punctuate tenderness gauge (PTG) to measure tenderness upon palpation. The subjects performed the exercises initially and then either at 6, 7, 8, or 9 weeks of the previous bout of exercise. The VAS and PTG were used at 24, 48 and 72 hours following the eccentric exercises. The results showed greater muscle tenderness and perceived pain at 24 and 48 hours after the exercise bout, resolving by 72 hours. The researchers concluded that performance of an eccentric exercise bout up to 9 weeks before beginning an exercise program can reduce delayed post-exercise muscle pain and tenderness.

A study by Seliger et al. compared maximum eccentric, concentric, and isometric contractions using EMG and energy expenditure in the quadriceps. They concluded that the force produced during the eccentric contraction was the greatest, but the energy expenditure was less then that of the concentric contraction.
Warren et al\textsuperscript{7} tested maximal eccentric contractions of the tibialis anterior muscle with EMG. They concluded that the repetition of maximal voluntary eccentric contractions produced an increased recruitment of type I slow-twitch motor units and a decrease in type II fast-twitch motor units. However, the results differed when sub-maximal eccentric isokinetic contractions were tested. McHugh et al,\textsuperscript{8} concluded that there was a greater proportion of fast-twitch motor units recruited during eccentric contractions, but as the eccentric contraction approached 100\% of the MVC, there was an equal proportion of fast-twitch and slow-twitch motor units being recruited.

The effects of concentric and eccentric overload strength training in women was studied by Hortobagyi et al.\textsuperscript{9} The women were tested by performing eccentric, concentric, isokinetic, and isometric contractions. The results indicated that the women gained, on average, 22\% of the total weight lifted over the seven days. The women in the study gained strength by exercising at low intensities over a short period of time. The eccentric overload training produced twice the strength gains as concentric training. The results followed the force-velocity relationship of the human skeletal muscle. The maximum load that can be lifted is limited by fatigue during the concentric phase, which means the eccentric phase is underloaded. Kaminski et al\textsuperscript{10} studied the strength gains in the hamstrings using a traditional concentric training protocol and an eccentric program using eccentric loads equal to the concentric one repetition maximum (1RM). The subjects were assigned to one of three groups: 1) eccentric, 2) concentric, and 3) a control group. Each of the subjects performed a hamstring curl on an isotonic weight machine to determine a pretest 1RM. The eccentric and concentric groups began a 6-week hamstring strength-training program each training twice a week. The concentric training
group performed two sets of eight repetitions at 80% of their 1RM value throughout the study. The eccentric group also performed two sets of eight repetitions, but the eccentric and concentric phases of the contraction were loaded differently. The concentric phase was loaded at 40% of the individuals 1RM, whereas the eccentric phase was loaded at 100% of the 1RM. The results showed that the eccentric training group had improved their 1RM to body weight ratio by 28.8% as compared to a 19.0% increase in the concentric training group. This supports the premise that eccentric training may increase strength training to a greater degree than concentric training. Only the eccentric training group produced increases in the eccentric isokinetic peak torque to body weight ratio.

The results indicated that eccentric, isotonic training produced significant improvements in eccentric isokinetic strength, while concentric isotonic training had no significant effect in eccentric isokinetic strength. Neither type of training had any significant effect on concentric isokinetic strength gains. The subjects were also closely monitored for DOMS throughout the study, but the only significant difference in DOMS occurred after the first day. DOMS did not affect the performance of the subjects throughout the remaining 6-week training period of the eccentric group.

Figure 1 provides a schematic overview of the multiple, interactive physiologic effects and responses of eccentric muscle loading.²
Eccentric exercise can have up to 120% mechanical efficiency.\textsuperscript{12} Whereas concentric exercise only has a efficiency range of between 13% and 26%. The efficiency and training effects of eccentric and concentric exercise are usually compared separately because most exercise machines were only able to work on the concentric phase of exercise.\textsuperscript{12-14,17} Current machines are capable of combining both concentric and eccentric exercise. Some researchers have analyzed the effect of both concentric and eccentric exercise in combination and what effect the combination had on strength and force.\textsuperscript{13,14} They found that training with both eccentric and concentric exercise combined (compared to concentric exercise alone) improved vertical jumps, force, and strength.\textsuperscript{13,14}

Red River Valley Sports Acceleration (Fargo, North Dakota) has recently acquired the use of the Agaton Max Series Leg. They implemented the Agaton into a training program for the Dickinson State University football team. The results showed
that subjects had gains in the unilateral and bilateral leg press, vertical jump, and sprints\textsuperscript{4} over a six-week time frame. The \textit{Agaton}'s main advantage is that it combines eccentric and concentric exercise into one leg press machine.

\textbf{Electromyography}

Electromyography (EMG) is a measure of the electrical activity of a muscle.\textsuperscript{12,15,16} Surface electromyography in biomechanics has three dominant applications: 1) to serve as an indicator for the initiation of muscle activation, 2) to determine the relationship to the force produced by a muscle, and 3) to serve as an index of the fatigue processes occurring within a muscle.\textsuperscript{15,16} In this study, EMG will be used to measure the activity of selected muscles. It is generally accepted that a concentric contraction gives a higher amplitude EMG signal than eccentric contractions of the same force.\textsuperscript{2,12,15} EMG activity for concentric contractions may exceed that of eccentric contractions by a factor of two to three.\textsuperscript{2} The reason eccentric contractions have a lower EMG signal than that of concentric contractions relates to the number of muscle fibers that are activated during a muscle contraction. As a muscle lengthens, its tension generating capacity increases so that fewer fibers can produce a given force and the force per fiber is greater. This is consistent with the theory that during eccentric contractions, fewer motor units bear the load than during concentric contractions. 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. A principle of contractions called the Elftman proposal, describes the ratio of eccentric force to concentric force. This principle states that the force production by different type muscle contractions produce follows the following hierarchy: eccentric>isometric>concentric. This relationship is consistent for all
muscles. This principle provides a basis for assessment of human dysfunctions of muscle and joint performance that can be expressed as the eccentric/concentric ratio. This ratio is important because for pain-free, normal and efficient function to occur, the ratio has to be a minimum of one. It is important that a machine that carries out both eccentric and concentric activity such as the Agaton provide this ratio.

The vastus lateralis (VL) is active in performing a leg press. A leg press can be described as starting in supine or slightly elevated position with the hip and knees flexed at 90°, then extending the knees and hip so that the legs are fully extended and then returning to the starting position. As the knee goes into extension, the levels of EMG activity go from high to low. Although the VL is active throughout knee extension, it is most active when the hip, knee, or both are flexed.

The biceps femoris (BF) acts on both the hip and knee joint and is active during extension of the hip. The gluteus maximus is most active in hip extension against resistance. The BF is active during hip extension and knee flexion regardless of which joint is moving. The EMG activity increases slightly during the second half of rising from a flexed knee position such as when beginning to perform a leg press.

Although the gluteus maximus (GM) is most active during resisted hip extension, it also shows activity during trunk extension and forward bending at the hip joint to assist in stabilization of the pelvis. The GM is active during the squat, helping to extend the hip as well as stabilize the pelvis. The GM activity is higher during the middle portion of the squat but it tends to decrease during the beginning and middle of the lift.

The erector spinae (ES) muscles are a prime mover for extension of the spine. It has been reported that these muscles are inactive during the initial movement of lifting
weights of up to 56 lbs. In order to prevent back strain during exercise, the exercise machine should be built to minimize activity in the ES. Keeping the lumbar spine in a lordotic position puts less stress on the back. The Agaton has a lumbar roll built into it to facilitate prevention of low back injuries, by maintaining the lumbar lordosis during exercise.
Subjects

Thirteen, healthy, male volunteers gave informed consent to serve as subjects in this study (Table 1). Inclusion criteria included: 1) ages between 18 to 30, 2) previous training on machines being used in the study, 3) no previous history of orthopedic or active trunk or lower extremity musculoskeletal pathologies that would put them at risk to injury or interfere with the study. The study was approved by the Institutional Review Board at the University of North Dakota in Grand Forks and was performed at Sports Acceleration in Fargo, ND (See Appendix A).

Table 1. Descriptive Statistics of Subjects.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>21</td>
<td>19-25</td>
</tr>
<tr>
<td>Height (inches)</td>
<td>71.1</td>
<td>66-76</td>
</tr>
<tr>
<td>Weight (pounds)</td>
<td>205.1</td>
<td>161-265</td>
</tr>
</tbody>
</table>

Instrumentation

All trials were performed on a Plyo Pres (Acceleration Products, Inc., Fargo, ND 58103) and Agaton Max Series Leg Press (Agaton Fitness, Inc., Moorhead, Mn 56560).
**Plyo Press**

The *Plyo Press* is specifically designed to increase quadriceps muscle activity while minimizing the stress on the body through use of cams, an inclined seat, inclined foot plate, and a long excursion of the sled.\textsuperscript{19,20} A diagram of the *Plyo Press* is presented in Figure 2. In the lumbar region, reduced stress is achieved by having a seat back that is 15° from horizontal. The inclined seat reduces the amount of lumbosacral flexion during the exercise, and reduces the amount of stress on the low back.\textsuperscript{3,4} At this seat angle, the ES muscular activity is low due to the decreased need for active spinal stabilization.\textsuperscript{20} The cams of the *Plyo Press* are specifically designed to maximize strength benefits.\textsuperscript{19,20} Three cams are used to vary the load to the athlete as the knee goes from the starting position of 90° of flexion to the fully extended position. The applied weight lifted equates to 75% of the applied weight at a knee angle of 90° of flexion, 100% of the applied weight is lifted with the knee at 45° of extension, and 125% of the applied weight is seen at full extension of the knee. These loads were chosen to mimic the strength curves of the various leg/thigh muscles at their different moments.\textsuperscript{19} The long excursion of the track (108 inches) and the inclined footplate at 15° from vertical are important for performing *Plyo Jumps* safely.\textsuperscript{19,20}
Figure 2. Plyo Press.
**Agaton Max Series Leg Press**

The *Agaton Max Series Leg Press* is a plate-stacked leg press that allows the user to lower more than 100% of the concentric weight in an eccentric fashion by the use of a pneumatic (air pressure) system. A diagram of the *Agaton Max Series leg press* is shown in Figure 3. The leg press consists of two separate pieces of equipment; the leg press carriage and DW-1 parent machine which houses the weight stacks. The user starts the exercise in the “down” position with the hips and knees flexed at or slightly greater than 90°. The subject presses against the foot plate extending his trunk, knees, and hips. As the lifter changes directions at the point of full knee extension (now returning to the “down” position) the machine is triggered adding the second, or eccentric stack to allow the user to lower a weight that is greater than his concentric load. One repetition is achieved when the full “down” position is reached again.

The *Agaton leg press* encompasses several of the same features as the *Plyo Press* such as an adjustable inclined foot press and the inclined seat chosen at 30° (versus 15° for the *Plyo Press*). The *Agaton* also has a long enough track (66 inches) to allow for performing jump squats similar to what was done with the *Plyo Jumps*, although this feature was not used in this particular study.
Figure 3. Agaton Max Series Leg Press.
Electromyography

The electromyographic data was collected by a Noraxon Telemyo 8™ telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ 85254). This data was transmitted to a Noraxon Telemyo 8 receiver and then digitized by an analog digital interface board in the Peak Analog Module™ (Peak Performance Technologies, 7388 S. Revere Parkway, Suite 601, Englewood, CO 80112-9765). The video and electromyographic data were synchronized using the Peak Event Synchronization Unit™. A foot switch was used to trigger the start of EMG collection by applying pressure to the switch with the subject’s ball of the foot. The foot switch was activated each time the subject pressed the ball of their foot down to begin a repetition on either the Plyo Press/Jump or Agaton. Once the foot switch was activated, a LED light was illuminated on the video image to show when collection began.

Video

Six reflective markers were placed on each subject to represent the landmarks of the 1) acromion 2) iliac crest 3) greater trochanter 4) joint line of the knee 5) lateral malleous and 6) fifth metatarsal to represent the body in the sagital plane. The camera used to film the activity was a Peak High-Speed Video™ 60/120 Hz camera (Peak Performance Technologies, 7388 S. Revere Parkway, Suite 601, Englewood, CO 80112-9765). During the trials, a camera frequency of 60 Hz and a shutter speed of 1/250 of a second were used. Trials were taped on a JVC model BR-S378U™ videocassette recorder (JVC of America, 41 Slater Drive, Elmood Park, NJ 07407). The videotape was encoded with a SMPTE time code generator.
After all trials were recorded, the video was digitized using the Peak Motus Software™ package. The tapes were played back on a Sanyo Model GVR-S955™ (Sanyo, 1200 W. Artesia Boulevard, Campton, CA 90220) videocassette recorder while digitizing the data.

**Electrode and Marker Placement**

The skin on the right trunk and lower extremity was shaved of any excess body hair and cleansed with alcohol to prepare the subject for placement of nine surface EMG electrodes. The following muscles monitored were: 1) erector spinae (ES), 2) gluteus maximus (GM), 3) biceps femoris (BF), 4) vastus lateralis (VL) (Table 2). The muscles were chosen based on previous studies performed on similar machines in which there is a high likelihood that these muscles would show activation during the activities.

Table 2. Origin, Insertion, and Action of Selected muscles.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Origin</th>
<th>Insertion</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Erector Spinae</strong></td>
<td>-Posterior iliac crest</td>
<td>-Cervical and thoracic</td>
<td>-Bilaterally extend trunk and head</td>
</tr>
<tr>
<td></td>
<td>-Posterior sacrum</td>
<td>transverse processes</td>
<td>-Unilaterally sidebend trunk</td>
</tr>
<tr>
<td></td>
<td>-Lumbar spinous processes</td>
<td>-Mastoid process</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Supraspinous lig.</td>
<td>-Spinous processes</td>
<td></td>
</tr>
<tr>
<td><strong>Gluteus Maximus</strong></td>
<td>-Posterior iliac crest</td>
<td>-Iliotibial tract</td>
<td>-Extend thigh</td>
</tr>
<tr>
<td></td>
<td>-Sacrotuberous ligament</td>
<td>-Gluteal tuberosity</td>
<td>-Laterally rotate thigh</td>
</tr>
<tr>
<td><strong>Biceps Femoris</strong></td>
<td>-Ischial tuberosity</td>
<td>-Head of fibula</td>
<td>-Extend trunk</td>
</tr>
<tr>
<td><strong>Vastus Lateralis</strong></td>
<td>-Lateral lip of linea aspera</td>
<td>-Lateral surface, top of</td>
<td>-Extend knee</td>
</tr>
<tr>
<td></td>
<td>-Greater trochanter</td>
<td>patella</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Tibial tuberosity</td>
<td></td>
</tr>
</tbody>
</table>
The placement of the electrodes was determined by finding the muscle belly based on measurements using anatomical landmarks (Figure 4). The ground electrode was placed on the right iliotibial band (IT band). The EMG signals were transmitted to a receiver unit and sent to a computer for display and recording of data.

The reflective markers were placed on the subjects over various landmarks to designate body position. The markers were illuminated on the video screen and captured on tape during the trials on the Agaton and Plyo Press. Marker placements were digitized, thus allowing for analysis of the trunk, hip, knee and ankle motions.

Protocol

Subjects were familiar with the equipment, from previous training. The subjects were positioned on the Plyo Press with their feet shoulder width apart, knees bent at a 90° angle, and their feet in the center of the platform. A complete squat consisted of the knee starting at 90° of flexion progressing towards 0° of knee extension, without locking the knees, and going back to 90° of flexion in the knee. Each subject performed a series of three squats using a weight equal to their body weight as resistance, followed by three Plyo Jumps (a horizontal jump on the Plyo Press leg press machine) with 82% of their maximum leg press. The leg position for the subjects was the same on the Agaton as it was on the Plyo Press, but the seat position on the Agaton was elevated to 30°. Each subject concluded the study by performing three repetitions on the Agaton with 82% of their Plyo Press 1RM concentrically and 200% of that amount eccentrically.
Data Analysis

Before the subjects were recorded on tape, the camera field was calibrated by videotaping a meter stick with illuminated ends. The videotape of each trial was captured onto the Peak™ system and cropped down to two cycles. The video was then digitized using the Peak system. Joint angles were calculated by the software to represent the joint motions for each subject. The EMG data was exported to Noraxon Myosoft™ software for analysis and quantification of mean activity levels. For each subject the level of EMG activity during an exercise trial was compared to the EMG activity during the baseline Plyo Press with a resistance level equal to each subject’s own body weight. The EMG activity was converted to a percent (normalized) using the following formula:

\[
\text{% Change in EMG} = \frac{\text{EMG Activity For Trial} - \text{EMG Activity For Plyo Press}}{\text{EMG Activity For Plyo Press}} 
\]

The normalized values were entered into SPSS™ statistical software for analysis. The statistical analysis performed was a repeated measures single factor ANOVA with a significance level (\(\alpha\)) of .05. The independent variables were the concentric Agaton exercise, the Plyo Jump, and the eccentric Agaton exercise. The dependent variable was the percent change from the dynamic baseline activity, obtained from the squat performed on the Plyo Press.
**Gluteus Maximus** - midpoint of a line running from the inferior lateral angle of the sacrum to the greater trochanter

**Biceps Femoris** - midpoint of a line from the ischial tuberosity to the lateral femoral condyle

**Vastus Lateralis** - along a line ¼ the distance from the lateral knee joint line to the ASIS and over the belly of the vastus lateralis

**Erector Spinae** - horizontally aligned with the L3-4 interspace, 4 cm lateral to midline


**Figure 4.** Electrode Placement for Lower Extremity Muscles.
CHAPTER IV

RESULTS

Concentric Agaton vs. Plyo Jump

The average percent change in muscle activity during the concentric phases of the Agaton Leg Press and the average activity during the Plyo Jump for the four muscles is presented in Table 3. The greatest percent change in muscle activity for the concentric phase of the Agaton and the Plyo Jump occurred in the GM muscle. The GM showed a negative 282.46% difference from the Agaton versus the Plyo Jump. The BF and the ES also showed negative percent differences from the Agaton versus the Plyo Jump. The ES had the least of these differences at negative 53.0%. The vastus lateralis was the only muscle that had a higher amount of activity on the Agaton versus the Plyo Jump with this difference being 91.77%. The data was then analyzed using repeated measures single factor ANOVA. The results are presented in Tables 4-7.

There was no significant difference in muscle activity in the VL ($\alpha = .262$) between the concentric Agaton and the Plyo Jump exercises. All of the other muscle groups tested (BF, GM, ES) showed a significant difference ($\alpha = .038, .002, .009$ respectively) in muscle activation between the Agaton and the Plyo Jump.
Table 3. Percent Change in EMG activity during Concentric *Agaton* and *Plyo Jump* exercise.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Average %Baseline</th>
<th>Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vastus Lateralis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric Agaton</td>
<td>611.77%</td>
<td>265.68</td>
<td>150.0-1192.0</td>
</tr>
<tr>
<td>Average Plyo Jump</td>
<td>551.31%</td>
<td>234.47</td>
<td>174-1046.0</td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>+91.77%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biceps Femoris</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric Agaton</td>
<td>374.92%</td>
<td>163.14</td>
<td>206.0-761.0</td>
</tr>
<tr>
<td>Average Plyo Jump</td>
<td>457.15%</td>
<td>229.07</td>
<td>230.0-881.0</td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-82.23%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gluteus Maximus</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric Agaton</td>
<td>1037.77%</td>
<td>366.43</td>
<td>371.0-1558.0</td>
</tr>
<tr>
<td>Average Plyo Jump</td>
<td>1420.23%</td>
<td>474.82</td>
<td>475.0-2370.0</td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-282.46%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Erector Spinae</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric Agaton</td>
<td>1547.62%</td>
<td>762.57</td>
<td>211.0-2951.0</td>
</tr>
<tr>
<td>Average Plyo Jump</td>
<td>1600.62%</td>
<td>612.51</td>
<td>397.0-2642.0</td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-53.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*a*EMG activity in concentric Agaton > EMG activity in Plyo Jump  
*b*EMG activity in Plyo Jump > EMG activity in concentric Agaton
Table 4. Repeated measures ANOVA of Concentric Agaton and Plyo Jump EMG activity in the Vastus Lateralis.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F ratio</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Subjects</td>
<td>1300874.462</td>
<td>12</td>
<td>108406.205</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>23761.385</td>
<td>1</td>
<td>23761.385</td>
<td>1.385</td>
<td>.262</td>
</tr>
<tr>
<td>Error</td>
<td>205868.615</td>
<td>12</td>
<td>17155.718</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>10323366.000</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Repeated measures ANOVA of Concentric Agaton and Plyo Jump EMG activity in the Biceps Femoris.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F ratio</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Subjects</td>
<td>852021.462</td>
<td>1</td>
<td>71001.788</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>43952.346</td>
<td>1</td>
<td>43952.346</td>
<td>5.437</td>
<td>.038</td>
</tr>
<tr>
<td>Error</td>
<td>97011.154</td>
<td>12</td>
<td>8084.263</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5493273.000</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6. Repeated measures ANOVA of Concentric Agaton and Plyo Jump EMG activity in the Gluteus Maximus.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F ratio</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Subjects</td>
<td>3545658.000</td>
<td>12</td>
<td>295471.500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>950799.385</td>
<td>1</td>
<td>950799.385</td>
<td>14.799</td>
<td>.002</td>
</tr>
<tr>
<td>Error</td>
<td>770982.615</td>
<td>12</td>
<td>64248.551</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>44538906.000</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7. Repeated measures ANOVA of Concentric Agaton and Plyo Jump EMG activity in the Erector Spinae.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F ratio</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Subjects</td>
<td>9532731.154</td>
<td>12</td>
<td>794394.263</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>18258.500</td>
<td>1</td>
<td>18258.500</td>
<td>.113</td>
<td>.743</td>
</tr>
<tr>
<td>Error</td>
<td>1947445.000</td>
<td>12</td>
<td>162287.083</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>75922255.000</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Concentric *Agaton* vs. Eccentric *Agaton*

The average percent change in muscle activity for the concentric phase and eccentric phase of the *Agaton Leg Press* for each of the four muscles is presented in Table 8. The greatest percent change (503.31%) in muscle activity for both the concentric and eccentric phase on the *Agaton* occurred in the ES muscles. The GM and VL also showed differences between the concentric and eccentric phases on the *Agaton* at 334.77% and 127.77% respectively. The BF had the smallest difference of muscle activity at 98.38%. In all cases, muscle activity was greater during the concentric phase of the leg press on the *Agaton* compared with the eccentric phase. The data was then analyzed using repeated measures single factor ANOVA. The results are presented in Table 9-12.

This comparison of EMG muscle activity showed a significant difference between the concentric phase and the eccentric phase of contraction on the *Agaton Leg Press* in all muscle groups. The differences were reported for the VL, BF, GM, and the ES as ($\alpha = .048, .001, .000, .004$) respectively.

Figure 5 shows the EMG activity, knee range of motion and stick man diagram for subject number four during one complete cycle on the *Agaton*.

A comparison of all EMG activity that was studied is presented in Figure 6. Note that the greatest percentage changes in muscle activity occurred in the gluteus maximus and the erector spinae muscles. The smallest percent change occurred in the biceps femoris.
Table 8. Percent Change in EMG activity during Concentric *Agaton* and Eccentric *Agaton*

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Average %Baseline</th>
<th>Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vastus Lateralis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric Agaton</td>
<td>611.77%</td>
<td>265.68</td>
<td>150.0-1192.0</td>
</tr>
<tr>
<td>Eccentric Agaton</td>
<td>484.0%</td>
<td>163.49</td>
<td>136.0-742.0</td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td><strong>+127.77</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biceps Femoris</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric Agaton</td>
<td>374.92%</td>
<td>163.14</td>
<td>206.0-761.0</td>
</tr>
<tr>
<td>Eccentric Agaton</td>
<td>276.54</td>
<td>116.95</td>
<td>113.00-463.0</td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td><strong>+98.38</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gluteus Maximus</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric Agaton</td>
<td>1037.77%</td>
<td>366.43</td>
<td>371.0-1558.0</td>
</tr>
<tr>
<td>Eccentric Agaton</td>
<td>703.00%</td>
<td>314.12</td>
<td>297.0-1415.0</td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td><strong>+334.77</strong>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Erector Spinae</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentric Agaton</td>
<td>1547.62%</td>
<td>762.57</td>
<td>211.0-2951.0</td>
</tr>
<tr>
<td>Eccentric Agaton</td>
<td>1044.31%</td>
<td>639.33</td>
<td>195.0-2843.0</td>
</tr>
<tr>
<td><strong>Difference</strong></td>
<td><strong>+503.31</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*aEMG activity in concentric Agaton > EMG activity in Eccentric Agaton*
Table 9. Repeated measures ANOVA of Concentric *Agaton* and Eccentric *Agaton* EMG activity in the Vastus Lateralis.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F ratio</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Subjects</td>
<td>904473.154</td>
<td>12</td>
<td>75372.763</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>106112.346</td>
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<td>106112.346</td>
<td>4.835</td>
<td>.048</td>
</tr>
<tr>
<td>Error</td>
<td>263343.154</td>
<td>12</td>
<td>21945.263</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9078545.000</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10. Repeated measures ANOVA of Concentric *Agaton* and Eccentric *Agaton* EMG activity in the Biceps Femoris.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F ratio</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Subjects</td>
<td>445430.615</td>
<td>12</td>
<td>37119.218</td>
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<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>62916.962</td>
<td>1</td>
<td>62916.962</td>
<td>19.829</td>
<td>.001</td>
</tr>
<tr>
<td>Error</td>
<td>38075.538</td>
<td>12</td>
<td>3172.962</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3305037.000</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11. Repeated measures ANOVA of Concentric *Agaton* and Eccentric *Agaton* EMG activity in the Gluteus Maximus.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F ratio</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Subjects</td>
<td>2502421.154</td>
<td>12</td>
<td>208535.096</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>728457.846</td>
<td>1</td>
<td>728457.846</td>
<td>29.852</td>
<td>.000</td>
</tr>
<tr>
<td>Error</td>
<td>292825.154</td>
<td>12</td>
<td>24402.096</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23220508.000</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 12. Repeated measures ANOVA of Concentric *Agaton* and Eccentric *Agaton* EMG activity in the Erector Spinae.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F ratio</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within Subjects</td>
<td>10302812.462</td>
<td>12</td>
<td>858567.705</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>1646571.115</td>
<td>1</td>
<td>1646571.115</td>
<td>12.504</td>
<td>.004</td>
</tr>
<tr>
<td>Error</td>
<td>1580195.385</td>
<td>12</td>
<td>131682.949</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>57197003.000</td>
<td>26</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 5. Example of single cycle muscle EMG on Agaton.
Figure 6. EMG Activity for Muscle Groups.
CHAPTER V

DISCUSSION

Muscle Activation on the Agaton Leg Press and Plyo Jump

In all the exercise modes, the Erector Spinae muscle group was found to have the greatest percent increase in activity. This may be due to the fact that during the dynamic baseline activity the ES was not recruited to help stabilize the pelvis since performing a Plyo Press using body weight does not require much effort. However, during the other exercise bouts, where the load was much greater, the ES may have been recruited to stabilize the low back. The lower extremity muscle groups are required as prime movers to complete the leg press, thus they are recruited with both light and heavy loads with the percent change being less in those muscles. Both the Agaton and Plyo Press were designed to focus on muscle activation of the lower extremity and to decrease trunk muscle activity. Therefore, the GM, VL, and the BF were more heavily recruited during the baseline activity as compared to the ES. This difference may account for the reported large increase in the ES muscle activity. The two machines, although built to recruit the quadriceps and gluteus maximus, vary in structure and design. The design differences may account for the reported difference in muscle activity. Slight differences in joint angle, weight bearing, and range of motion between the machines can also affect how muscles are recruited. In addition, we did not control for velocity of contraction. The subjects were able to choose the speed, which was most comfortable for them. Due to the
fact that increasing the velocity of a contraction increases the EMG activity in the muscle this may have further confounded the results of our study.\textsuperscript{24}

**Concentric Agaton vs. Eccentric Agaton**

For all four muscle groups tested during the concentric and eccentric phases on the *Agaton* the concentric phase showed more EMG activity. This is despite the fact that during the eccentric phase of the contraction the muscle was loaded 200\% of the concentric phase. It is known that eccentric muscle contractions have less EMG activity than concentric contractions.\textsuperscript{2} However, with the 200\% loading with eccentric activity in this comparison the EMG results were expected to have less of an overall difference. This can be accounted for by the muscle recruitment involved with each type of contraction. Eccentric contractions recruit Type II muscle fibers, which subsequently have on average larger motor units and produce larger amounts of EMG activity. The exact opposite is true for concentric contractions, which recruit Type I muscle fibers. Subsequently, with increased resistance during a concentric contraction most if not all of the Type I fibers are recruited and the muscle begins utilizing Type II fibers, which than increase the EMG activity quickly. The reverse is true for eccentrics. These types of contractions recruit Type II fibers first and when more recruitment is needed due to increases in resistance Type I fibers begin to be utilized. Due to the differences in motor unit size between Type I and II fibers the relative increases in EMG activity in muscles during the eccentric phase is less than would be expected with a 200\% load. A primary reason that activity from eccentric contractions is less is that the muscle can effectively use the elastic elements in order to generate tension.\textsuperscript{25} Therefore, for the eccentric contraction to have the same amount of tension as concentric contractions, there needs to
be less activity in the contractile component. Subsequently, the EMG activity of eccentric contractions is generally less. Our results agree with this theory.

**Limitations**

To allow for the comparison of EMG signal intensity levels between subjects and exercise modes, quantification of EMG activity was performed. The normalized EMG was used as a dynamic baseline of muscle activity in which to compare all subsequent findings for both the Agaton and Plyo Jump. The use of a dynamic baseline instead of a maximal voluntary contraction (MVC) is one possible reason why the results of this study are different than previous studies. Burden and Bartlet stated that MVC and not dynamic baseline activity should be used to normalize the amplitude of EMG’s if the objectives are to compare them between muscles, tasks or individuals. However, Marras and Davis contend that MVC data is less useful than dynamic baseline for normalization when subjects may be unwilling to perform a maximal contraction secondary to injury or extenuating circumstances. During the comparison of the Agaton and Plyo Jump the subjects were assumed to be healthy based on their consent to participate. MVC in theory elicits maximal firing levels of all motor units of a particular muscle and therefore may have given this study different results compared to other studies completed in this area.

The fact that two different machines were used to compare the EMG activity of two different exercises made it difficult to analyze the resulting data between them. The original study compared the mean EMG of the Plyo Jump at 80% of the subjects 1 RM to the concentric phase of the Agaton at 80%. To allow for a more meaningful data analysis, comparisons could have been made between the concentric phase of the Plyo
Jump versus the concentric phase of the Agaton using the same resistance at 80% of the 1 RM. Likewise, the eccentric phases of both machines at 80% of the 1 RM could have been compared. Further, a comparison could then have been made between the same concentric phase as mentioned above and the eccentric phase of the Agaton at 200% of the concentric phase. This would have allowed for the comparison of results of the Plyo Jump to the Agaton at: 1) 80% during the concentric phase and 80% during the eccentric phase of both machines, 2) 80% during the concentric phase on the Plyo Jump and 200% during the eccentric phase of the Agaton. Solely concentrating on comparing the Agaton to itself would be beneficial. This would allow relevant data to be compared for contractions on the Agaton at: 1) 80% during the concentric phase to 80% during the eccentric phase and 2) 80% during the concentric phase to 200% during the eccentric phase. By doing this, the researcher would have EMG data specifically on the differences in muscle activation for the Agaton when using different resistance levels.

Finally, eccentric training has been shown to produce greater levels of delayed onset muscle soreness (DOMS) than concentric training.2,10 Since little research has been completed monitoring the level of DOMS for eccentric training of this magnitude, it would have been beneficial for the researchers to look at this as well. Each subject could have completed a subjective questionnaire about their DOMS levels, from none to severe at 24, 48, and 72 hours post exercise for this study. This information could then have been used to monitor injuries, muscle adaptations, or training effects that came about because of the eccentric training.
Conclusion

In summary, the purpose of this study was to provide a comparison of muscle activity in the back and lower extremities between a Plyo Jump and a leg press on the Agaton Max Series Leg Press. The results of this study showed, except for the VL, that there was a significant difference in the EMG activity produced. There was more change in EMG activity in the BF, GM and ES on the Plyo Jump than there was on the Agaton, and there was a greater difference in muscle activity in all four muscle groups during the concentric phase of the contraction on the Agaton as compared to the eccentric phase.
University of North Dakota Human Subjects Review Form

Please Note: The policies and procedures of the University of North Dakota apply to all activities involving the use of Human Subjects performed by faculty, staff and students 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 procedure governing the use of human subjects. When preparing your Human Subjects Review Form, use the attached “IRB Checklist”.

Please provide the information requested below:

Principal Investigator: Thomas M. Mohr, Lee E. Nagle, Thayne L. Bosh, Kelly C. Jorschumb, Tonya M Kunze

Telephone: 777-2831 Address: P.O. Box 9037, University of North Dakota

E-mail address: ___________________________

School/College: Medicine Department: Physical Therapy

Student Adviser (if applicable): Thomas M. Mohr

Telephone: 777-2831 Address: P.O. Box 9037, University of North Dakota

E-mail address: ___________________________

School/College: Medicine Department: Physical Therapy

Project Title: Electromyographic and Motion Analysis of Trunk and Lower Extremity Muscle Activity Using the Plyo Press and the Agaton Max Series Leg Press.

Proposed Project Dates: Beginning Date: 06/02 Completion Date: 06/03

Funding agencies supporting this research:

(A copy of the funding proposal for each agency identified above MUST be attached to the proposal when submitted.)

YES or NO Does the Principal Investigator or any researcher associated with this project have a financial interest in the results of this project? If yes, please submit on a separate piece of paper an additional explanation of the financial interest (other than receipt of a grant)

If your project has been or will be submitted to another Institutional Review Board (s), Please list those boards below along with the status of each proposal.

Type of Project: Please Check Yes or No to the following.

YES or NO New Project

YES or NO Continuation/Renewal

YES or NO Protocol Change for previously approved project (resubmit “Human Subjects Review Proposal” with changes bolded or highlighted and signed)

Cooperating Institution: Frapper Acceleration, Fargo, North Dakota

YES or NO Will any institution of agency personnel assist in the Proposed Project? Copies of letters indicating the willingness of the institution/agency to cooperate in the study and an understanding of the study MUST be attached. Letters must include the name and title of the individual signing the letter and, if possible, should be printed on letterhead.
Subject Classification: This study will involve subjects who are in the following special populations: Check all that apply.

- Minors (<18 years)
- Prisoners
- Pregnant Women/Fetuses
- Persons with impaired ability to understand their involvement and/or consequences of participation in this research
- UND Students
- Other Athletes training at Frappier Acceleration in Fargo, ND

For information about protections for each of the special populations please refer to the protected populations section on the Office of Research and Program Development website.

This study will involve: Check all that apply.

- New Drugs (IND)
- Non-approved Use of Drug(s)
- Recombinant DNA
- Fetal Tissue
- Stem Cells
- Other (Discarded tissue, fluids, blood, etc.)
- None of the above will be involved in this study

I. Project Overview
Please provide a brief explanation (limit to 200 words or less) of the rationale and purpose of the study, introduction of any sponsor(s) of the study, and justification for use of human subjects and/or special populations (e.g., vulnerable populations such as minors, prisoners, pregnant women/fetuses).

In the quest to improve individual athletic performance, new training equipment and methodologies are being designed daily. The eccentric benefits of isometric strength training have long been heralded but training eccentrically has been challenging. Measuring the effects of eccentric exercise has been difficult. The Agaton is a machine that has been specifically designed for concentric/eccentric training employing variable, independent loads in the two phases (concentric & eccentric) of lifting. The purpose of this research project is to provide data on motion analysis and muscle activity for the Agaton Max Series Leg Press and compare it with the Plyo Press. During the study subjects will perform three repetitions at 82% concentrically and 140 and 200% eccentrically of their 1-RM concentric maximum.

II. Protocol Description
Please provide a succinct description of the procedures to be used by addressing the instructions under each of the following categories. Individuals conducting clinical research please refer to the “Guidelines for Clinical-Research Protocols” on the Office of Research and Program Development website.

1. Subject Selection.

a) Describe recruitment procedures (i.e., how will subjects be recruited, who will recruit them, where and when they will be recruited and for how long) and include copies of any advertisements, fliers, etc., that will be used to recruit subjects. It is anticipated that we will recruit twenty subjects (both male and female) between the ages of 18 and 30. The subjects for the study will be recruited by Frappier Acceleration and presently enrolled in their training program.

b) Describe your subject selection procedures and criteria, paying special attention to the rationale for including subjects from any of the categories listed in the “Subject Classification” section above.

The subjects will be chosen by their age, training and health status.

c) Describe your exclusionary criteria and provide a rationale for excluding subject categories.

Subjects will be healthy with no history of orthopedic or active trunk or lower extremity musculoskeletal pathologies that would interfere with the study or put the subject at risk for injury.

d) Describe the estimated number of subjects that will participate and the rationale for using that number of subjects. Approximately 20 subjects will used so that the data will more closely represent the athletic population in general.

e) Specify the potential for valid results. If you have used a power analysis to determine the number of subjects, describe your method.

EMG and motion analysis have been proven valid and reliable in measuring muscle activity and motion of the joints.

2. Description of Methodology.

a) Describe the procedures used to obtain informed consent.

Subjects will read and sign the informed consent form. One of the researchers will be available to answer any questions posed by the subjects.

b) Describe where the research will be conducted.

Research will be performed at the training facility of Frappier Acceleration in Fargo, ND.

c) Indicate who will carry out the research procedures.

The principle investigators will be responsible for set-up and collection of the data.

Attachments Necessary: Copies of all instruments (such as survey/interview questions, data collection forms completed by subjects, etc.) must be attached to this proposal.


a) Clearly describe the anticipated risks to the subject/others including any physical, emotional, and financial risks that might result from this study.

b) Describe precautions you will take to minimize potential risks to the subjects (e.g., sterile conditions, informing subjects that some individuals may have strong emotional reactions to the procedures, debriefing, etc.).

4. Subject Protection

a) Describe procedures you will implement to protect confidentiality (such as coding subject data, removing identifying information, reporting data in aggregate form, etc.).

b) Indicate the subject will be provided with a copy of the consent form and how this will be done.

The actual experiment will consist of doing three repetitions at each percentage of the one repetition maximum on the Agaton and Plyo Press. Subjects will be randomly selected to either the Plyo Press or Agaton. Rest breaks of 3-5 minutes will be provided between trials.

Descriptive statistics describing the subjects' anthropometric profiles will be provided. Statistical analysis will be performed on the integrated EMG activity during the trials and will be compared with the MVC data as a percentage using normalized EMG. The video image of the subject will be converted to a stickman-like figure, from which we can determine joint angles and velocity. The EMG data is synchronized with the video data to determine the level of EMG activity during the various exercise trials.

e) Describe audio/visual procedures and proper disposal of tapes.

Video Analysis will be used to measure lower extremity and trunk range of motion during the activity. Reflective markers will be attached to the trunk and lower extremity using double-sided adhesive tape. We anticipate placing markers on the trunk, hip, knee, ilium and ankle. Video cameras will be placed on the side of the subject and will film the subject's trunk and lower extremity markers and motion during the experimental trial. This will be recorded on videotape and will be transferred to a computer for analysis. The video file will be kept at the UND Physical Therapy Department for three (3) years and then destroyed.

f) Describe the qualifications of the individuals conducting all procedures used in the study.

The principal investigators have taken course work and have been instructed in proper use of EMG and motion analysis equipment as well as set-up and data collection.

g) Describe compensation procedures (payment or class credit, etc.)

None

Attachments Necessary: Copies of all instruments (such as survey/interview questions, data collection forms completed by subjects, etc.) must be attached to this proposal.
IV. Consent Form

A copy of the Consent Form must be attached to this proposal. If no Consent Form is to be used, document the procedures to be received, etc.). Clearly describe the benefits to the subject and to society resulting from this study (such as learning experiences, services received, etc.). Please note: payment is not a benefit and should be listed in the Protocol Description section under Methodology.

The data will be stored in the Department of Physical Therapy at the University of North Dakota for (3) years. Only the researchers will have access to the data. Both the data and the consent forms will be destroyed by shredding after the period of storage has expired.

d) Describe procedures to deal with adverse reactions (referrals to helping agencies, procedures for dealing with trauma etc.). In the event that a trauma should happen emergency personal will be notified to ensure that the subject is given proper medical treatment.

e) Include an explanation of medical treatment available if injury or adverse reaction occurs and responsibility for costs involved.

In the event that this research activity results in physical injury medical treatment will be available, including first aid, emergency treatment, 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 the participant and their third party payer, unless the reason for treatment is due to negligence on the part of the researchers.

III. Benefits of the Study

Clearly describe the benefits to the subject and to society resulting from this study (such as learning experiences, services received, etc.). Please note: payment is not a benefit and should be listed in the Protocol Description section under Methodology.

The data produced by this study will be beneficial in providing support for the utilization of the Agaton Max Series Leg Press in strength training as a dynamic strengthening tool. At the present time, research on this machine is needed to help provide knowledge about its design functions and promote its use in programs where safe and efficient strength training is incorporated. The results of this study will help to determine the difference in muscle recruitment of the Agaton and the Plyo Press compared to a MVC which can then support the use of the these two machines 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 Agaton Max Series Leg Press on the athletic population.

IV. Consent Form

A copy of the Consent Form must be attached to this proposal. If no Consent Form is to be used, document the procedures to be used to protect human subjects. Refer to the ORPD website for further information regarding Consent Form Regulations.

Please note: Regulations require that all Consent Forms, and all pages of the Consent Forms, be kept for a minimum of 3 years after the completion of the study, even if subject does not continue participation. The Consent Form must be written in language that can easily be read by the subject population and any use of jargon or technical language should be avoided. It is recommended that the Consent Form be written in the third person (please see the examples on the ORPD website). A two inch by two inch blank space must be left on the bottom of each page of the consent form for the IRB approval stamp. The consent form must include the following elements:

a) An introduction of the principal investigator
b) An explanation of the purposes of the research.
c) The expected duration of subject participation.
d) A brief summary of the project procedures.
e) A description of the benefits to the subject/others anticipated from this study
f) A paragraph describing any reasonably foreseeable risks or discomforts to the subject.
g) Disclosure of any alternative procedures/treatments that are advantageous to the subject
h) A description of how confidentiality of subjects and data will be maintained. Indicate that the data and consent forms will be stored separately for at least three years following the completion of the study. Indicate where, in general, the data and consent documents will be stored and who has access. Indicate how you will dispose of the data. Be sure to list any mandatory reporting requirements that may require breaking confidentiality.
i) An explanation of compensation/medical treatment available if injury occurs
j) The names, telephone numbers and addresses of two individuals to contact for information (generally the student and student adviser). This information should be included in the following statement: “If you have questions about the research, please call (insert Principal Investigator’s name) at (insert phone number of Principal Investigator) or (insert Adviser’s name) at (insert Adviser’s phone number). If you have any other questions or concerns, please call the Office of Research and Program Development at 777-4279.”
k) If applicable: an explanation of who to contact in the event of a research-related injury to the subject.
l) If applicable: an explanation of financial interest must be included.

m) RE: Participation in the study:

1) An indication that participation is voluntary and that no penalties or loss of benefits will result from refusal to participate.

2) An indication that the subject may discontinue participation at any time without penalty with an explanation of how they can discontinue participation.

3) An explanation of circumstances which may result in the termination of a subject's participation in the study.

4) A description of any anticipated costs to the subject.

5) A statement indicating whether the subject will be informed of the findings of the study.

6) A statement indicating that the subject will receive a copy of the Consent Form.

By signing below you are verifying that the information provided in the Human Subjects Review Form and attached information is accurate and that the project will be completed as indicated.

Signatures:

Date: ------------------------------------------------------ ------------------------------- (Principal Investigator)

Date: ------------------------------------------------------ ------------------------------- (Student Advisor)

Requirements for submitting proposals:

Additional information can be found at Office of Research and Program Development website at www.und.nodak.edu/dept/orpd

Original Proposals and all attachments should be submitted to: Office of Research and Program Development (ORPD), P. O. Box 7134, Grand Forks, ND 58202-7134, or drop off at Room 105, Twamley Hall.

The criteria for determining what category your proposal will be reviewed as is listed on page 3 of the IRB Checklist. Your reviewer will assign a review category to your proposal. Should your protocol require Full Board review, you will need to provide additional copies. Further information can be found on the ORPD website regarding required copies and IRB review categories or you may call the ORPD office.

In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency (agreement/contract if there is no proposal) must be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 7 copies if the proposal is clinical-medical. If the proposed work is being conducted for a pharmaceutical company, 7 copies of the company's protocol must be provided.

Please Note: Student Researchers must complete the attached "Student Consent to Release of Educational Record".

Federal regulations require that key personnel involved in human subject research complete educational training. The UND IRB has chosen an online educational course, which can be found at www.miami.edu/citireg, for this training. The online Educational Modules must be completed before approval is granted for a proposal. In addition, Principal Investigators must provide a list of the key personnel involved in the project to ORPD, so the office can maintain records of those individuals that have completed training.

Revised 7/27/2001
INFORMATION AND CONSENT FORM

TITLE: Electromyographic and Motion Analysis of Trunk and Lower Extremity Muscle Activity Using the Plyo Press and Agaton Max Series Leg Press.

You are being invited to participate in a study conducted by Thayne Bosh, Lee Nagle, Kelly Jorschumb, Tonya Kunze and Thomas Mohr from the Physical Therapy department at the University of North Dakota. The purpose of this study is to compare muscle activity in the trunk and lower extremities using both the Plyo Press and Agaton Max Series Leg Press. We will be using video analysis to determine the position of the joints while performing the exercise. Only normal, trained, healthy subjects will be asked to participate in this study. If you have any previous history of orthopedic or active trunk or lower extremity musculoskeletal pathologies that would interfere with the study or put you at risk for injury, you will not be eligible for this study. The benefit for you, as the participant, will be the experience of being involved in a scientific study and knowing that you will be contributing to the body of knowledge in exercise physiology and physical therapy.

You will be asked to perform a maximum voluntary contraction before you begin the exercise on the Plyo Press or Agaton Max Series Leg Press. You will then perform three repetitions concentrically (muscle shortening) at 82% of the one repetition maximum followed by three repetitions eccentrically (muscle lengthening) at 140% and 200% of the one repetition maximum.

The study will take approximately one hour of your time. You will be asked to report to Frappier Acceleration in Fargo, ND at an assigned time. You will then be asked to change into dark colored gym shorts for the experiment. We will first record your age, gender, height and weight. During the experiment, we will be recording the amount of muscle activity and the position of the joints while you are performing each exercise.

Although the process of physical performance testing always involves some degree of risk, the investigators in this study feel that the risk of injury or discomfort is minimal. In order for us to record the muscle activity, we will be placing electrodes on your trunk and lower extremity. The recording electrodes are attached to the surface of the skin with an adhesive material. We will need to shave the areas where the electrodes are being placed. We will also be attaching reflective markers at various points on your trunk and lower extremity. These devices only record information from your muscles and joints, they do not stimulate the skin. A video camera will be used to film your walking and the reflective markers will be used as a template to construct stickman like figures from the position of the markers. After we get the electrodes and markers placed, we will give you a training session on the Plyo Press and Agaton Max Series Leg Press. The amount of exercise you will be asked to perform will be moderate to maximum. There may be slight redness of the skin following the removal of the electrodes, but this will only be temporary.
Your name will not be used in any reports of the results of this study, and the video files will be converted to stickman like diagrams for analysis and stored on a computer. Your real, photographic image will not be used in reporting of the findings of the study. The computer files and consent forms are kept in the University of North Dakota Physical Therapy Department for a period of three (3) years. After that time, the electronic media is erased and the paper files are shredded. Any information that is obtained in connection with this study and that can be identified with you will be confidential and will be disclosed only with your permission. The data will identified by a number known only by the researcher. The researcher or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

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

In event that this research activity (which will conducted at Frappier Acceleration) results in 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, unless the reason for treatment is due to negligence on the part of the researchers. By signing this document, you are not giving up any legal rights you may have in case of negligence or other legal fault of anyone that is involved in the study.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION; I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this study explained to me by one of the researchers.

Participant's Signature  Date
REFERENCES


15. Deluca CJ. The use of surface electromyography in biomechanics. Presented at: The International Society for Biomechanics; July 5, 1993; Boston, MA.


