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Effects of Eccentric Strengthening on Force Output of the Erector Spinae as Measured by Surface Electromyography (EMG)

By

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Research Practicum

Submitted to the Physical Therapy Department at Grand Valley State University
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MASTER OF SCIENCE IN PHYSICAL THERAPY

1998
Abstract

Effects of Eccentric Strengthening on the Force Output of the Erector Spinae as Measured by Surface Electromyography (EMG)

The purpose of this study was to determine the increase in force output of the erector spinae using the mean amplitude of surface electromyography (EMG) before and after an eccentric exercise program. Eight healthy subjects, two men and six women, between the ages of 30-45 were individually dosed and evaluated for baseline recordings of their EMG activity during three isometric and six eccentric contractions of their lumbar erector spinae. The exercise program consisted of a single eccentric lowering exercise of six repetitions for three sets, two times a week, for four weeks. EMG recordings were taken in posttest measurements during three isometric and six eccentric contractions at the end of the study. Pretest and posttest data were compared using the Wilcoxon signed rank test for paired data (α = 0.05). There is insufficient evidence to conclude that a four week eccentric training protocol had an effect on the force output of the erector spinae as measured by surface EMG.
Dedication

We would like to dedicate this project
to our Parents.
Thank you for being there!
Acknowledgments

We would like to thank and acknowledge our Committee; Barb Baker, Committee Chairperson; Dan Vaughn, Committee Member; Justine Ritchie, Committee Member; The members of the Walker Ambucs; Grand Valley State University Physical Therapy Department; GVSU faculty; and the GVSU Physical Therapy Students; and Dr. Xavier Drèze, from the University of Southern California, for all their help and support of this project.
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Chapter 1
Introduction

The Problem

The primary focus of today's back rehabilitation is on functional tasks. Research investigating these functional tasks typically focuses on lifting techniques. Yet, two out of three work-related injuries to the lower back occur during lowering tasks (DeLooze, Toussaint, VanDieen & Kemper, 1993). When back muscles act together to lower an object, the muscles lengthens under the load and contract eccentrically. In many work environments, the low back muscles operate in this manner as well as in pushing, pulling, and carrying objects. This eccentric muscle activation plays an important role not only in work related tasks but in everyday activities and sports as well. Research shows eccentric tasks to be as equally significant as concentric muscle activation. In the multitude of research that has investigated the functional and biomechanical movement of the lower back, little work has been done in the area of lowering tasks. Clinical application and the effects of functional eccentric exercise training on back muscles and pathologies have not, as of today, been thoroughly investigated (Kellis & Baltzopoulos, 1995), (Albert, 1995).

Background of Problem

The Back Pain Epidemic

Investigation into effects of eccentrics on back musculature is important for several reasons. Low back pain is a prevalent problem in the United States today. Rehabilitation is
costly and time consuming. Over 80% of adults will experience low back pain (LBP) at some point in their lives costing over 40 billion dollars (Kraus & Marcus, 1997), (Nelson, O'Reilly, Miller, Hogan, Wegner, & Kelly, 1995). Recurrence of back pain from the same pathology is common and decreases quality of life and work capability. Therefore, eccentric training integrated into a functional rehabilitation program may have many potential benefits such as decreased cost and rehabilitation time.

Functional Use of the Back

Back muscles are used almost continuously in functional patterns. Back muscles are required for trunk stability, which is necessary for quality movement of extremities, posture and ambulation for everyday activities. Research is continuing to define the biomechanical and physiological principles surrounding low back function. Investigation in recent years has helped quantify singular movements such as forward flexion, side bending, and rotation (Lavender, Chen, Trafimow & Anderson, 1995), (Mayer, Kondraske, Mooney, Carmichael & Butsch, 1989), (Toussaint, VanBaar, Langen, DeLooze, & VanDieen, 1992). By isolating separate trunk movement research has shown how and when trunk muscles are activated. Additionally, several studies have looked into the biomechanics of functional patterns such as lifting from the squat position (Delitto & Rose, 1987), (Holmes, Damaser & Lehman, 1992), (Vakos, Nitz, Threlkeld, Shapiro & Horrn, 1994). This work also supports information about movement patterns of low back muscles during everyday functions. Functional use as it applies to the health profession has been investigated by Garg and colleagues in several studies evaluating patient transfers. In these studies, the methods preferred were those involving pulling techniques in which the lower back is in a lengthened position (Garg, Owen, Beller & Banaag, 1991). Although this does not
directly imply the use of eccentrics, it does demonstrate that the back is used often in a position that may benefit from eccentric strengthening. In a study looking at sit to stand biomechanics of the elderly, researchers found erector spinae muscles to be the first to activate during the sit to stand maneuver. Here, erector spinae work eccentrically to control the forward bend of the trunk prior to weight shift forwards (Millington, Myklbust & Shambes, 1992). It is clearly shown in a review of current research that eccentric contractions have been observed in low back research but have never been directly investigated.

Eccentric Exercise

Eccentric protocols have demonstrated increased muscle performance over a short period of time (Albert, 1995). As a result of the more efficient oxygen metabolism, faster cross-bridging mechanism and the contribution of energy from the muscles' passive elastic structures. During eccentrics, it has been shown that eccentric exercises may be shorter in duration and less frequently performed and still result in increased muscle performance (Albert, 1995). Functional use of eccentric exercise also works well along side the principal of specificity training (Foster, Hector, Welsh, Schraper & Snyder, 1995), (Sale, 1988), (Wilson, Murphy & Walshe, 1996), (Kellis, et al., 1995), (Albert, 1995). These principles' state that exercises mimicking a functional task will demonstrate greater improvement in strength than exercise performed in non-functional patterns. Factors for this improvement could be: neural adaptations, preferential recruitment of specific muscle fiber types, theoretical application of the size principal, theoretical changes to muscle spindle action, increased fiber hypertrophy and endurance. Many of these factors are characteristics explained during use of eccentric muscle contractions.
General Methods

The specific effect this study has investigated is force output of the erector spinae group. Force output is an indirect measurement of muscle strength and has been used as a valid measurement in many studies. Integrated surface electromyography (iEMG), a standard and valid technique used in the collection of muscle activation data from the erector spinae muscles was used to collect the data (Mannion & Dolan, 1995), (DeLuca, 1993), (Vandieen, Toussaint, Thissen & VandeVen, 1993), (Cassisi, Robinson, O'Conner & MacMillan, 1993), (Mayer, et al., 1989). As demonstrated in other studies investigating force output, we had hoped to see increases in strength of the erector spinae group collected by a similar EMG technique over a four-week course of specific eccentric exercise. The experimental group, composed of healthy individuals, underwent a four-week exercise program. Exercise was performed twice a week with data collection prior to, during and after the study. Specifically, the eccentric exercise was a repeated lowering task. Subjects lowered a weighted box while standing in a pelvic stabilizing frame. Data were collected and analyzed comparing pre- and post-exercise to determine any statistical significance in force output of erector spinae musculature.

The Purpose of Study

The purpose of this study was to determine the effect of functional eccentric contractions on erector spinae muscles while these muscles lengthen under a load. The specific effect investigated was force output (strength) of the erector spiniae.
Significance of Problem to Physical Therapy

Results of this study may eventually lead to better understanding of the role eccentric contractions play in low back functional rehabilitation. By strengthening muscles with lengthening contractions, erector spinae muscles should perform better when called upon to lower, push, pull or catch a heavy object. Theoretically, they should also contribute to a better performance of concentric contractions during movement in the opposite direction (Kellis, et al., 1995). Functional movement such as lifting an object or standing up from a seated position may be better facilitated.

Populations that will benefit from eccentric work are numerous. The populations that may benefit most are people around 30 to 50 year age range (Waddell, 1987). During the third through fifth decades of life, back morphology changes as a result of normal aging, misuse, disuse or disease. A better understanding of the effects eccentric contractions have on low back morphology may help decrease the incidence of low back pain. Additionally, results of this study may contribute to current knowledge of the lumbar musculoskeletal function.

According to Waddell, (1987), the main theme of physical rehabilitation must change from rest to rehabilitation and the restoration of function. Nelson et al., follows a similar theme in noting that the trend in the 1990's is toward a more aggressive "sports medicine " approach. Following Waddell's and Nelson's ideas, the development of an eccentric back rehabilitation regimen may have a productive and efficient role in the physical therapy clinic. Additionally, results of this study may contribute to current knowledge of the lumbar musculoskeletal function.
Hypothesis

Loaded, lengthening contractions (eccentric exercise) performed in functional patterns with pelvic stabilization will improve strength of the erector spinae muscle group.
Chapter 2
Literature Review

The study of eccentrics and the erector spinae muscles covers a wide variety of topics. Literature reviewed for this study will attempt to cover concepts needed to show how eccentric exercise may affect low back musculature. The review covers literature describing erector spinae morphology as well as definitions and important concepts of eccentric contractions. Low back pain prevalence is demonstrated and the possible need for better back rehabilitation will also be shown through past research. Current rehabilitation for low back pain is examined along with areas of lumbar musculoskeletal biomechanics. Discussion includes why eccentrics may be beneficial to the function of the erector spinae and functional use of the low back. Lastly, why muscle force, or strength, will be collected by electromyography techniques similar to those used in other research investigating muscle force output.

The authors of this study will have shown through this review of current literature the lack of research on eccentric contractions as it relates to the lumbar erector spinae. With this review the authors hope to establish the need for this research and demonstrate the importance of the data collected at the conclusion of this study.

Low Back Pain Prevalence

Low back pain (LBP) is a common diagnosis seen in physical therapy clinics with 8 out of 10 adults experiencing LBP at some point in their lifetime. LBP is often referred to as a
universal condition that is considered normal. Consequently, people often dismiss their low back dysfunction and do not seek medical treatment. Sixty percent of the normal population will experience LBP every year (Waddell, 1987). This pathology may result in a disability that has dramatically increased throughout Western society in the last century. Along with affecting a majority of the population, insurance companies and the workplace also experience the side effects. With regard to health care utilization and lost time from work, LBP causes the greatest problem in the middle working years of life with peak age being 40 years old (Waddell, 1987). The magnitude of the problem is shown in that 50% of worker's compensation costs are due to this type of injury. Low back pain costs over 40 billion dollars per year and worker's compensation disability is growing at 14 times the population growth (Nelson, et al., 1995).

Low Back Research

Normals versus Chronic Low Back Pain (CLBP)

The need for back rehabilitation is evident in much of today's current literature. Many studies have shown atrophy, decreased endurance, altered physical characteristics and movement patterns between non-pathological and pathological low back musculature. In a comparison study with chronic low back pain patients (CLBP) and controls, Cassisi et al., (1993), looked at the differences in strength and electromyographic (EMG) activity between the two groups. The researchers found that CLBP patients demonstrated lower lumbar muscle strengths and lower EMG activities than control subjects. The authors of this study suggest that patients can be identified as having LBP on the basis of muscle function. Cassisi and his researchers have shown that chronic LBP patients can be differentiated into having what they call, a muscle dysfunction component.
Another study by Esola et al., (1996), looked at movement patterns of subjects with and without a history of low back pain. EMG studies show that as the forward bending moment on the spine increases, it is controlled by the increasing activity of the erector spinae muscle group. Altered movement patterns of the lumbar spine and hips during forward bending may explain why forward bending is a risk factor for LBP. The conclusions were that people with a history of low back pain had similar amounts of lumbar spine and hip motion during forward bending as the control group but that the pattern of motion was different. Low back pain (LBP) patients tended to move with more motion in the lumbar spine during the early part of trunk flexion (0 to 30 degrees) compared to control groups. They also found that patients with LBP also demonstrated a significantly lower lumbar to hip flexion ratio and decreased hamstring flexibility. It is important to note that many activities of daily living are performed in a partial forward bent position such as brushing your teeth and vacuuming. The earlier lumbar spine movement places an earlier stress on posterior elements of the lumbar spine. Over time this repetitive microtrauma may lead to cyclical injury and pain (Esola, McClure, Fitzgerald & Siegler, 1996).

Paquet et al., (1994), suggested a decreased ability to relax the erector spinae at the end of flexion, plus abnormal hip to spine ration movement in patients with LBP. It has been suggested in all the studies reviewed that this inequality of movement leads to development of low back pain (Paquet, et al., 1994), (Esola, et al., 1996), (Cassisi, et al., 1993).

In 1996, Ito et al., demonstrated in a reliable test that CLBP patients demonstrated decreased trunk muscle endurance in timed, sustained trunk flexion and extension positions as when compared to subjects without chronic back pain (Ito, Shirado, Suzuki, Takaahashi, Kaneda, & Strax, 1996).
Hultman et al., (1993), demonstrated decreased strength, endurance, erector spinae density (total muscle fiber area) and tension force-per-unit-area in subjects with LBP compared to normals. The study looked at middle age men with no history of LBP, intermittent LBP and chronic LBP. Hultman's group found decreasing extensor torque using an isokinetic dynamometer and decreased isometric endurance values from healthy to intermittent to chronic LBP subjects. Tension force development was also significantly less in chronic LBP patients than the other two groups. They stated that this could suggest an inability to develop tension force per unit muscle area and an inability to recruit muscle fibers. Hultman also examined the muscle composition, density and area of their subjects. They found a decrease in muscle density which they stated may mean there is increased fat content and less contractile tissues or atrophy of muscle fibers secondary to disuse (Hultman, Nordin, Saraste & Ohlsen, 1993). The gradual decrease of strength, endurance and associated factors from normal to intermittent LBP to chronic LBP seem to suggests that this is an ongoing process and individuals with borderline physical abilities may be at risk for chronic LBP.

Changes to muscle fibers also occur with LBP. Decreases in fiber size and strength of 30 patients with chronic LBP were investigated in a study by Rissanen et al., (1995). Researchers found in the pre-study muscle biopsy a decrease from the normal size of the type II, fast twitch muscle fibers of the low back multifidi muscles. There is still debate on the reason for this atrophy. After a comprehensive three-month low back rehabilitation program, Rissanen did demonstrate statistically significant increases in size and strength of these type II fibers (Rissanen, Kalimo, & Alaranta, 1995).

In conclusion, research presents evidence to suggest that in subjects with LBP there are several changes from normal subjects. These changes include: altered movement of the hips and
lumbar spine in forward flexion, decreased endurance and altered muscle physiology. This suggests the need for further investigation into rehabilitation methods that will improve low back movements, muscle function and morphology towards normal.

Research on Current Back Rehabilitation

During the last decade many forms of back rehabilitation have been investigated. The overall conclusion seems to indicate that strengthening exercises for the low back are more beneficial than rest for many low back pathologies (Foster, 1991), (Norris, 1995). At the same time, these studies suggest that more work needs to be done to collect specific data for each exercise program and pathology.

There are many different points of view on the best way to exercise during low back rehabilitation. One of the most common methods for strengthening programs is Dynamic Lumbar Stabilization. Another common method is the use of specific pelvic stabilization in conjunction with a strengthening program (Nelson, et al., 1995), (Foster & Fulton, 1991), (Graves, Webb, Pollock, Matkozich, Leggett & Carpenter, et al., 1994). A good example of a current pelvic stabilization is a method from Australia called Active Lumbar Stabilization which has become popular in recent years (Norris, 1995). Of the two methods of exercise programs, researchers agree that pelvic stabilization with strengthening has been shown to be more effective in increasing low back strength compared to non-stabilized exercise programs.

A third area being researched in low back rehabilitation is a growing opinion that "high tech" equipment such as computerized machines are not as good as "low tech" equipment such as free weights. The results of this review suggest the need to develop new low back exercise programs which are performed without the benefit of large, expensive exercise machines (Sach,
Ahmad, LaCroix, Olimpio, Heath & David, et al., 1994), (Timm, 1994). Several studies investigating low back rehabilitation sited in this literature review also indicate a need for continued investigation and data collection on many of the suggested rehabilitation programs.

Research on Functional Back Movement

Much of the negative work performed by the erector spinae is functional. Negative work is defined as work done by a muscle when it tries to halt the movement of a joint, as in decelerating the body during walking or running (Balnave & Thompson, 1993). Eccentric muscle actions involved in lowering, pulling, rotation, or side bending of contralateral erector spinae are used everyday in functional patterns (Garg, et al., 1991), (Pink, Perry & Jobe, 1993), (Millington, et al., 1992). One functional action in particular includes forward flexion of the trunk, which is effected strongly by the position of the lumbar spine. Lumbar erector spinae function eccentrically during forward flexion to assist in controlling flexion momentum (Kendall, McCreary & Provance, 1993).

In recent years functional movement patterns in subjects with and without pathologies are being clearly defined. It is important in today's research to investigate back motion as it is used in daily activities. This allows for direct clinical application and integration of information into current rehabilitation technique.

DeLooze and colleagues performed a study in 1993 looking at joint moments and muscle activity during lowering tasks. DeLooze et al., states in his research that in studies looking into manual materials handling, or heavy manual labor, almost all studies investigate lifting. Many manual labor jobs incorporate lowering activities as well as carrying, pushing and pulling. He sites Lamone et al., in a 1987 study stating that two out of three injuries occur during lowering
activities. During a lowering, or eccentric, activity DeLooze et al., found lower EMG activity than concentric lifting activities. They suggest that fewer motor units are being activated to produce forces equal to those found in comparison to lifting. These lowering forces occur over a smaller cross sectional area such as the erector spinae, and because of this, may create a greater risk of injury to muscles and their attachments (DeLooze, et al., 1993).

Over the last decade, Dr. Steven Lavender and colleagues have performed several studies of the lower back. During this time they have continued to carefully define the muscular action of the back during individual functional movements. In 1992 he and his colleagues conducted a study on co-contraction during twisting and moment direction and magnitude (Lavender, Tsuang, Anderson, Hafezi & Shin, 1992). The results showed large changes in muscle recruitment due to the asymmetric motion of twisting, but only small changes activation levels because of the increased moment magnitude. Next, he investigated and quantified muscle activation during twisting through 12 bending moments and found increases in ipsilateral erector spinae muscle and contralateral external oblique muscle (Lavender, Tsuang, & Anderson, 1993). During 1994 Lavender and his researchers looked into the EMG quantification of erector spinae and found that during loading of the subjects right side, there was increased muscle activation on the contralateral low back muscles during forward flexion and backward bending. In both directions, there was little activation of the anterior trunk musculature (Lavender, Trafimow, Anderson, Mayer & Chen, 1994). Then in 1995 they performed two studies on the anticipatory effects that sudden loading has on erector spinae. They found that when sudden loads were anticipated, the back muscles were tensed. They also found that if the subject was aware of when the sudden loading would occur, there was a change in the preparatory co-contraction of the trunk muscles. This change was due to the increased torque generated by the erector spinae and a decrease in
torque generated by the anterior trunk muscles (Lavender, et al., 1995). Steven Lavender and his colleagues are just one group of several researchers collecting data on the multitude of low back motions and EMG muscle activity. Their research is very inclusive yet, this is a good example of how the question of effects of lowering eccentric movement on the low back, has not yet been investigated.

Benefits of Functional Exercise and Specificity Training

Different body movements require the ability to exert force during multiple angular velocities as the joints move through an available range of motion. Various combinations of these angular velocities are used for every specific functional body movement. To increase the body's functional muscle performance it is important to train the muscles in the specific movement patterns required for the functional movement. Duncan, Chandler & Cavanaugh, (1989) was sited by Kellis et al., reporting that an experimental group training eccentrically had significant improvements in eccentric strength at all angular velocities tested (Kellis, et al., 1995).

Other recent research by Wilson and colleagues looking at specificity of training includes investigation of "posture" on functional activities. Posture, or body position, can be defined as the body's movement specific to a function or task. These studies show that exercise results in greater improvement when performed in the functional task they attempt to facilitate (Wilson, et al., 1996). The results of Wilson's study stresses the importance of selecting exercises in which the movement closely resembles the task the exercise is attempting to improve.

A research study by Sale et al., (1988), suggests, "Strength performance depends on not only quantity and quality of involved muscle but also upon the ability of the nervous system to
appropriately activate the muscle. Specificity of training may cause adaptive changes within the nervous system which allow prime movers to more fully activate in specific movements and to better coordinate the activation of all relevant muscles."

Foster et al., (1995), took a different approach as his study researched cross training exercises which improve performance despite the principle of specificity. The results showed an increase in performance did occur with cross training, however there was greater improvement with specificity training.

Training specific muscles for a particular function can be accomplished in a variety of ways. Specificity training is functional and produces faster and more efficient results. Eccentric training of the lumbar erector spinae is specific and functional. Rehabilitation incorporating eccentric back exercise may produce greater results than conventional back programs, which only focus on the concentric exercise. Given the specific morphology of erector spinae, functional eccentric training may lead to better muscle performance during activities of daily living.

**Eccentric Contractions**

Eccentric contraction (EC) occurs when a muscle lengthens as it exerts a force and so performs what is commonly referred to as negative work. Negative work is done by a muscle when it tries to halt the movement of a joint. Muscles operate eccentrically during many everyday functional activities such as lowering an object to the floor, descending stairs or during quick deceleration of a motion (Balnave, et al., 1993), (Albert, 1995).

Eccentric muscle contractions demonstrate several interesting characteristics. First, lengthening contractions produce greater tensions per cross-sectional area of muscle than
concentric or isometric contractions. According to Kisner and Colby (1990), eccentric contraction is also velocity dependent and increasing the speed of contraction and muscular length against a heavy load will generate greater tension. This may be a mechanism for protecting a muscle during excessive loading (Kisner & Colby, 1990). However, other studies have shown eccentric contraction is not velocity dependent (Kellis, et al., 1995). Secondly, eccentric activation demonstrates lower EMG activity perhaps suggesting fewer motor units activated. Finally, eccentric training may also contribute to concentric force through the use of the passive elastic structures which store energy during eccentric muscle activation (Kellis, et al., 1995), (Albert, 1995).

Eccentric contractions have been studied on several peripheral joints and muscles. These studies may have led to new rehabilitation programs for various joint pathologies based on the beneficial effects of eccentric contractions. Tendon pathologies such as elbow and patellar tendinitis and hamstring strains have shown faster rehabilitation with eccentric protocols (Wilks, Voight, Keirns, Gambetta, Andrews & Dillman, 1993), (Keskula, 1996), (Jensen, Warren & Laursen, 1989), (Stanish, Rubinovich & Curwin, 1986), (Bennett & Stauber, 1986). This information suggests that eccentrics may be beneficial to low back exercise as the erector spinae muscles have numerous individual musculotendinous insertions and origins. In light of the lack of available research in this area, the authors of this study believe the effects of eccentric contractions on the erector spinae need further investigation.

**Erector Spinae**

To understand why eccentric training may benefit erector spinae functions, it is helpful to have a complete understanding of the erector spinae muscle. The following sections will discuss
in detail the physiology, force output, type II fiber preference, muscle spindle involvement, delayed onset muscle soreness, and the effects of different exercise parameters of eccentric contractions and morphology.

Morphology

Erector spinae (ES) is used as a collective term for three major lumbar muscles: iliocostalis, longissimus, and spinalis. Although studies have shown this muscle to consist of many separate and specifically arranged fibers, the combined actions work together in uniform patterns (Moore, 1992). Erector spinae have long been thought to be involved with lumbar back pathologies as they are prime movers in extension activities (Fiebert, & Keller, 1994), (Macintosh & Bogduk, 1987). Originating from a broad tendon attached inferiorly to the posterior aspect of the iliac crest, posterior aspect of the sacrum, and inferior lumbar spinous processes, they insert on the transverse processes of the thoracic vertebra. Actions of the erector spinae act bilaterally to extend the trunk and unilaterally to sidebend and rotate the trunk toward the opposite direction (Moore, 1992).

The erector spinae are a group of long flat muscles with parallel, overlapping fibers. In general, lumbar fibers arise from the lumbar accessory and transverse processes and insert independently on the erector spinae aponeurosis into the ilium. These fibers range from 3 to 19 cm in length depending on the attachments of the fascicle. They consist of small muscle bellies and one rostral and one caudal tendon (Macintosh, et al., 1987), (Bogduk, 1992). As force generation of muscle is related to cross sectional area, the slender, long erector spinae may benefit from the greater force generation by eccentric contractions.
Distribution of muscle fiber types gives an indication of the metabolic profile and functional capacity (Thorstensson & Carlson, 1987). Fiber type distribution varies between individual muscles and even between the same muscle in different people. Predominance of type I fibers, called slow twitch, have been found in tonic postural muscles. Type II fast twitch fibers are predominant in phasic or dynamic muscles (Basmajian & Deluca, 1985). Although the erector spinae can be involved in dynamic movements of the trunk, erector spinae morphology consists of fewer type two fibers than average muscle (Thorstensson, et al., 1987), (Rantanen, Hurme, Falck, Alaranta, Nykvist & Lehto, et al., 1993), (Sirca, 1985). In addition to the smaller percentage of type II fibers they are also uncharacteristically smaller in diameter as well (Ratananen, et al., 1993).

Ratio composition of fiber types in the ES show a predominance of type I. These type I fibers are of typical diameter and density. Total average cross sectional area at the L4-5 level showed 57% type I and 17% type II with the remaining 26% nonmuscular tissue (NMT): fat, fibrous connective tissue, nerves, and blood vessels. Average type II percentage in men was 19.5 compared to women at 10.9. Diameter of type I fibers was 55.1 μm in men and 51.6 μm in women. The type II fiber diameter was 38.8 μm in men and 28.4 μm in women demonstrating a highly significant difference (p<0.001). Average diameter of fibers for average muscles is 40-50 micrometers (μm) (Basmajian, et al., 1985). Age does not seem to be a factor in fiber size (Rantanen, et al., 1993).

Passive Elastic Structures and Stretch Shortening Cycle

Enclosing the erector spinae is a large, passive, elastic tissue structure called the thoracolumbar fascia (TLF). The TLF contains the deep muscles of the back and extends from
the 12th rib to the iliac crest. Lateral attachments are on the internal oblique muscle and transverse abdominus muscles. Medially the attachments are the transverse and spinous processes of the spine. The two interior compartments enclose the erector spinae and the quadratus lumborum. As noted earlier, passive elastic structures (PES), such as the TLF and muscle tendons, play an important role in eccentrics as it may be possible to transfer energy stored during an eccentric contraction into any reciprocal concentric action (Albert, 1995), (Wilks, et al., 1993). This energy transfer through the PES is facilitated by an action called the stretch shortening cycle. Pousson and colleagues, VanHoecke, & Goubel, determined that an eccentric strength training program performed on elbow flexors caused changes in the PES characteristics. They found a decrease in compliance of PES because of the stretch shortening cycle. This decrease results in the inability to store potential energy in the PES which can then be released during a stretch shortening cycle (Pousson, et al., 1989). Exercises which incorporate stretch shortening cycles utilize a fast lengthening contraction, or stretch, preceding the concentric contraction and may be beneficial to the erector spinae because of the large amount of PES. (Kellis, et al., 1995).

Force Output

The mechanism for eccentric force output is unclear and there are many factors that may contribute to it. One factor that has been postulated is that the cross-bridging detachment during eccentric contractions is different than for concentric or isometric contractions. During eccentric activation, no energy is required for cross bridge detachment (Kellis, et al., 1995), (Lieber, 1990). This difference may in part account for the greater force output of a muscle during eccentric contractions than during concentric or isometric contractions (Kellis, et al., 1995), (Kisner, et al.,
Muscle fiber orientation also contributes to force by allowing for specific muscle function and corresponding force generation. Architectural structure of ES fibers are predominately parallel. Typically, parallel fibers such as those found in the erector spinae generate the least force for large muscle excursion (Lieber, 1990). Force is also proportional to physiologic cross sectional area. Erector spinae cross sectional density as determined on healthy subjects is around 44 cm² (Hultman, et al., 1993). Muscle contraction velocity, which is related to force, is proportional to muscle fiber length. The long length of ES fibers may predetermine these muscles to a slower reaction time.

It has been generally accepted that the faster a muscle eccentrically contracts, the faster tension within the muscle is formed (Kisner, et al., 1990). We can look to several parameters to see why. In eccentric and concentric contractions both the length tension relationship and cross bridging action occur differently (Lieber, 1990), (Albert, 1995). Length tension relationships during eccentric contractions demonstrate that skeletal muscle is very resistant to lengthening and yet is independent of velocity. Activated muscles are forced to lengthen due to high external loads. The other parameter to consider is the cross-bridging mechanism. Cross bridging mechanisms during excitation coupling theoretically cause adaptations producing optimal overlay between actin and myosin elements. As a result, force output is increased. Cross bridging occurs at a faster rate resulting in a decrease in energy expenditure from aerobic metabolic system. High forces are generated by the muscle at relatively low metabolic cost (Lieber, 1990).
Type II Fibers

A major consideration for the use of eccentrics on the erector spinae is the preferential recruitment of type II (fast twitch) muscle fibers during eccentric contraction. It is known that type II fibers develop greater tension, hypertrophy and strength than type I (slow twitch) fibers (Basmajian, et al., 1985), (Kisner, et al., 1990). Preferentially hypertrophied type II fibers could lead to an increase in force per unit area. This has been found in elite power athletes and may suggest long term exercise programs may be needed to achieve benefits (Jones, Newham, Round, & Tolfree, 1987). Since eccentrics predominately select type II fibers, the fibers of the somewhat morphologically unique erector spinae may benefit from the increased strength and efficient metabolism of eccentric contractions.

The importance of the fiber composition is demonstrated by the size principle of motor unit recruitment. As force is generated by a muscle to overcome a load, additional motor units are recruited. Motor neurons are recruited in an orderly fashion. The fibers with smaller motor units are recruited before fibers with larger motor units.

Type I (slow twitch) are smaller and recruited first as contraction is initiated. They are more excitable, have smaller motor neurons and are found predominately in tonic or postural muscles.

Type II (fast twitch) fibers are faster and larger and are not recruited unless increased force generations required to overcome a load placed on the muscle. The motor neurons for these fibers are larger than slow twitch and have faster conduction velocities, larger axons and generate greater tension. The type II fibers may atrophy quicker than type I but this depends on the individual muscle (Basmajian, et al., 1985).
Typically, all muscles have type I and type II fibers. Fibers are further subdivided into fast fatigueable (FF), fast glycolytic (FG), and fast oxidative glycolytic (FOG). The composition and arrangement of these fibers are specific to the use and action of that muscle. Erector spinae fiber composition is not morphologically similar to any other skeletal muscle fibers with the singular exception of the masseter muscle. In the erector spinae, the fiber diameters are reversed (Albert, 1995), (Mannion, et al., 1995). According to the size recruitment principle, these smaller fibers should be recruited before the larger type I fibers. This preferential recruitment may be done by the derecruitment of slow muscle motor units with the selective activation of fast muscle motor units. There is a possible neural mechanism for this (Nardone & Romano, 1988). Research in this area is inconclusive (Mannion, et al., 1995). Little work has been done to determine fiber type distribution and their effect on force output in the erector spinae.

In previous studies involving eccentric training, enlarged fibers were found to be type II FG fibers (Frieden, et al., 1990), (Leiber, 1990), (Jones, et al., 1987). This could be due to the oxidative capacity of fibers during fiber damage. There are two theoretical mechanisms for this. One mechanism states FG fibers fatigue early in exercise periods. As they cannot regenerate ATP, they enter a rigor or highly stiffened state. The stretch of these stiff fibers during lengthening disrupts the fiber resulting in cytoskeletal and myofibril damage. Continued endurance training with eccentrics results in increased muscle oxidative capacity and the change from FG to FOG fibers. FOG fibers do not fatigue as readily as FG fibers and so repeated exercise will cause less damage. A second possible mechanism begins again with FG fibers fatiguing early in exercise. Next, mitochondria lose their calcium buffering capacity. This increases intracellular calcium and results in activation of the calcium-activated neural and lysosomal proteases, normally active in denervation (Lieber, 1990).
Eccentric Oxygen Metabolism

The metabolism of eccentric contraction is also more efficient requiring less oxygen uptake. Oxygen utilization during eccentric exercise is 70-75% less than concentric exercise. Aerobic metabolism is important in excitation coupling, as it is needed to initiate the actin-myosin complex. Dissociation between these elements occurs during the cross-bridging cycle of excitation-coupling in muscle cells. During eccentric contractions, less adenosine triphosphate (ATP) is required as actin and myosin form into optimal alignments. Decrease in ATP use results in a decreased need for oxygen during contraction (Lieber, 1990), (Albert, 1995), (Pahud, Ravussin, Acheson & Jequier, 1980).

Muscle Spindle Activation

Muscle spindle action may play an important role during eccentric force generation. Extrafusal muscle fibers influence intrafusal muscle spindle firing to produce a physiologic change or "history" for the spindle. Elevated discharge rates and lasting alterations have occurred after isometrics from previous studies (Wilson, Gandevia, & Burke 1995). Any increase in the firing rate will therefore increase muscle tension and rate of response. Increase in stretch sensitivity is related to the "history" of the intrafusal length changes. Much of the information is theoretical and needs further investigation on how they affect eccentric contractions. These theories may lead to a better understanding of the effects of this study (Romano, & Schieppati, 1986), (McMahon, 1997), (Nardone, et al., 1988), (Lieber, 1990), (Bell, & Wenger, 1987), (Macefield, Hagbarth, Gorman, Gandevia & Burke, 1990), (Wilson, et al., 1995), (Kyrolainen, & Komi, 1994).
Delayed Onset Muscle Soreness (DOMS)

Although there are several benefits to eccentric exercise, a disadvantage is the prevalence of delayed onset muscle soreness (DOMS). This microcellular damage is associated with eccentric exercise and it can be severe. Microcellular damage causing delayed onset muscle soreness (DOMS) lasts two to four days after exercise. Although there is currently no known way to prevent DOMS, adaptive responses to muscle damage have been demonstrated in just one repeat bout of eccentric exercise. With each repeat bout of exercise the reoccurrence of DOMS diminishes (Brown, Child, Donnelly, Saxton & Day, 1996), (Ebbling, & Clarkson, 1990), (Mair, Mayr, Muller, Koller, Haid, & Dworzak, 1995), (Nosaka, & Clarkson, 1995).

The effects of DOMS have been well documented. High-force tension levels per cross sectional area generated from eccentric contractions may be the reason for muscle fiber damage and subsequent soreness (Golden, & Dudley, 1992). This soreness has variable intensity and duration depending on exercise protocol used. Preferentially recruited type II fibers are also those fibers that are damaged during lengthening contractions. DOMS produces pain and soreness peaking at 12-24 hours post exercise (Berry, Moritain, & Tolson, 1990). Balnave et. al. reported DOMS peaking 24-48 hours post exercise. There is damage to sarcomere architecture and a release of soluble muscle enzymes, most notably creatine kinase (CK). Infiltration of mononuclear cells does not cause this soreness (i.e. immune response) but is a result of damage (Jones, et al., 1987). Duration of effects is variable. Studies on the prevention of DOMS using vitamins C and E and concentric exercise are inconclusive (Jakeman, & Maxwell, 1993), (Maxwell, Jakemen, Thomason, Leguen, & Thorpe, 1993), (Meydani, & Evans, 1993), (Warren, Jenkins, Packer, Witt, & Armstrong, 1992).
Eccentric Exercise Parameters

The duration, frequency, and intensity parameters of exercise can alter many of the DOMS effects. Several studies show the effects of varying the parameters of eccentric exercise and influence to DOMS duration and recovery periods.

In a study by Newham et al., (1987), three sessions of eccentric exercise were performed on a group of subjects once every two weeks for 20 minutes at maximum intensity. Results showed that DOMS was greatest after first session then progressively decreased. Strength decreased 50% but recovered to 80% after 2 weeks, and recovery of force-frequency curve was faster after the 2nd and 3rd sessions. Balnave et al., (1993), looked at a 40 minute downhill walking program with a 25% grade at 6.4 kmh once-per-week for eight weeks. The slow-moving eccentric contraction caused increased damage and DOMS, which peaked over a period of 24-48 hours. In the Balnave study, DOMS did disappear by the second bout of exercise. In a study by Berry et al., (1990), eccentric exercise protocol consisting of only 15 minutes on 46 cm step, alternating one leg doing concentric motion and the other leg doing an eccentric motion. EMG recorded baseline 1, 12, 24, 48 hours post exercise and found DOMS at 12-24 hours at 1.8 -5.9 on a 10-point pain scale. EMG activity was highest immediately after to one-hour post exercise. DOMS was found to be still present at 48 hours. Lastly, a study by Golden et al., (1992), investigated strength decreases, not DOMS. Subjects performed ten 40-minute eccentric exercise bouts of 10 reps with 3 minutes rest between bouts every three weeks for six weeks. After the second bout of exercise, the subjects did not show the strength decreases they had shown after the first bout of exercise. Golden states this is a protective mechanism perhaps caused by neural adaptations.
During examination of exercise parameters from other studies, it is clear to the researchers of this study that avoidance of DOMS is unlikely. Our goal is to minimize these effects and still retain benefits of eccentric exercise.

**Electromyography (EMG)**

**Definitions and Electrophysiology**

Electromyography or EMG is defined as the study of electrical signals associated with the contraction of muscle (Perry, 1992). The basic unit of the body's neuromuscular contraction system is called the motor unit and consists of the alpha motor neuron and all the muscle fibers (cells) it innervates (Hamill, 1995). As the nerve impulse travels down the axon of the alpha motor neuron, to synapse with the muscle fibers and continue as the motor unit action potential a detectable electrical signal is formed. It is the summation of these motor unit action potentials under the electrode that leads to the generation of the EMG signal (Hamill, 1995). This signal can then be recorded and processed to determine the timing, and relative intensity of the muscular contraction (Perry, 1992). In this study we hope to follow other studies which have used EMG to estimate the relative amount of force that occurs during a muscle contraction.

**Relation to Force Output**

Several investigators have concluded that EMG may be a useful method of estimating the relative amount of force output from the motor units recruited in a muscle contraction. Winter states that "voluntary muscular activity results in an EMG that increases in magnitude with the tension" (Winter, 1990). Another investigator found that the amplitude of the EMG signal gives an estimate of the force produced by the muscle (Sward, Svensson, and Zetterberg, 1990). Still
another investigator found that while the relationship is not perfectly linear, EMG can provide insight into the force developed by a muscle. That is, 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 (Vakos, Nitz, Threlkeld, Shapiro, and Horn 1994). This study also used the amplitude of the EMG signal to correlate the increased muscle activity with an increase in the muscles' force output (Vakos, et al., 1994).

Sale reports that surface EMG has been shown to increase after strength training involving isometric contractions and eccentric contractions (1988). Komi and Hakkinen found that the average maximum IEMG increased after a twelve week concentric/eccentric training program, when measured during maximal and submaximal isometric contractions (1983). These increases in average maximum EMG also coincided with a significant increase in maximal peak isometric force as compared from pre-to-post test measurements (Komi and Hakkinen, 1983). Mooney, et al. used isometric testing to obtain baseline measurements for an eight-week eccentric/concentric protocol and reported that the amplitude of the EMG signal increased as resistance increased (1997). Hortobagyi, et al. reported that after an eccentric strengthening protocol lasting 12 weeks, subjects had improved eccentric and isometric force output by 116 and 45% respectively (1996). Additionally, the increases in eccentric and isometric force output were accompanied by increased EMG activity associated with eccentric contractions (by 188%) and isometric contractions (by 58%) (Hortobagy, et al., 1996).

Type and Placement of Electrodes

There are two types of electrodes used in EMG studies, those placed on the surface of the skin and those implanted in the muscle belly. Surface electrodes are useful when recording the
activity of large, superficial muscles (Turker, 1993). There are two types of surface electrodes, active and passive. Active surface electrodes have a built in signal amplifier and are not sensitive to electrode-skin interference. Passive electrodes have no indwelling amplifier and are sensitive to electrode-skin interference (Turker, 1993). While active electrodes are generally preferred over the passive type, passive electrodes will be used in our study due to the lack of availability of the active type. Since the passive electrodes will be used, several steps will be taken to reduce the amount of interference between the skin and the electrode. These steps include cleaning and shaving of the skin surface to remove dead cells and hair and then washing the skin with an alcohol wipe (Turker, 1993).

Winter states that "most EMGs require two electrodes over the muscle site, so that the voltage waveform that is recorded is the difference in potential between the two electrodes (1990)." This set-up is called a bipolar set-up and is considered advantageous to monopolar set-up (Turker, 1993). Turker states that the main advantage of using a bipolar set-up is it allows for the noise-suppressing capacity of the amplifier to be fully utilized (1993). Additionally a ground electrode is usually placed over an area of skin overlying bone, such as the kneecap, sternum, or forehead (Turker, 1993).

Another factor, which may add noise to the EMG signal, is the electrical activity originating from other muscles other than the muscle under study. This extraneous electrical activity is termed cross talk (Turker, 1993). Winter states that "surface electrodes are limited to detecting motor unit action potentials from those fibers quite close to the electrode site and are not prone to pickup from adjacent muscles (called crosstalk) unless the muscle being recorded is very small (1990)." Another author concluded that "the crosstalk problem in surface recording in negligible for most biomechanical studies in which standard EMG recording protocol is
employed, yet a warning is issued against the indiscriminate recording of surface EMG from muscles covered by adipose tissue (Solomomow, 1994)." In our study we will be using a standard protocol for electrode placement, which has been shown to maximize the activity of the erector spinae, while minimizing the cross-talk from surrounding muscles (Mannion and Dolan, 1996).

**Recording EMG/Processing EMG**

The electrodes are used to record the algebraic sum of the motor unit action potentials along the muscle at that point in time (Winter, 1990). Turker describes a series of steps taken to record and process EMG signals. Initially, a raw signal is collected using the electrodes. At this time the important characteristics of the raw signal are its amplitude, duration and frequency. The raw signal consists of positive and negative reflections to correspond with the depolarization and repolarizations of the motor unit action potentials. The next step is to rectify the signal. Rectification takes the absolute value of the negative and positive reflections and adds them together (Turker, 1993). The signal can then be further processed depending on the direction of data interpretation. Sward et al, describe a process for estimating force output by taking the root mean square values of recorded signal amplitudes over a given time and expressed in microvolts (1990). Other investigators have taken the area under the curve, attained through the integration of the rectified signal to determine force output (Turker, 1993).

**Normalization and Reliability of EMG Data**

Ahern, Follick, Council, and Laser-Wolston concluded that erector spinae EMG can be reliably measured using both static postures and dynamic movements, both within-session and
between sessions (1986). Most authors agree that to improve the reliability of surface EMG studies, its data should be normalized before it is analyzed. Normalization is performed to "accommodate the individual variation in the number and mixture of motor units sampled by the electrode" (Perry, 1992). Even careful electrode placement on the muscles surface cannot insure that any two applications will produce the same data quantitatively. Some factors which may attribute to this difference in EMG intensity are the small size of muscle fibers, the fiber type composition, the dispersion of motor units, fiberous tissue within the muscle, and variations in the contour of individual muscles (Perry, 1992). Therefore, before you can compare the EMG intensity between two muscles, the same muscle on different days, or from study to study, the EMG difference due to the motor unit sample must be excluded through normalization (Perry, 1992), (Turker, 1993). The normalization process involves "treating the functional data from each electrode as a ratio (usually expressed as a percentage) of some reference value" (Perry, 1992).

Perry states that the most convenient reference for normalization is the EMG activity measured during a maximum effort test (Perry, 1992). Other authors such as Knutson, Soderberg, Ballantyne, and Clarke agreed with Perry, concluding that the most common and reliable method of normalization has been to use the EMG data taken from the maximum voluntary isometric contraction (1994), (Turker, 1993).
Chapter 3
Materials and Methods

Study Design

The investigators initially designed this study to follow a pretest-posttest control group experimental design (Portney and Watkins, 1993). The researchers chose this design to measure the effects of eccentric exercise on the force output of the erector spinae muscles using surface electromyography (EMG). The subjects were to participate in one of two groups; a control group or an exercise group. Subjects in each group were to participate in an initial pretest to determine baseline values for their erector spinae force output. Subjects who were to participate in the eccentric exercise group, the experimental group, would have then undergone a four-week, two-day-a-week training program. Those in the control group would have resumed their normal routines for these four weeks. Additionally, members in both groups would have been remeasured for the force output of their erector spinae through a posttest at the end of the four weeks.

With the initial pretest-posttest control group design, the independent variable would have been the eccentric exercise, or in the case of the control group, the absence of exercise. The dependent variable would have been the force output of the erector spinae muscles as measured by surface EMG. Both groups would have been measured at similar times to make statistical comparisons. Statistics would then have been applied to determine whether there was a
significant difference in the change in force output of the experimental group versus that experienced by the control group.

After failing to obtain a sufficient number of subjects to fill both a control group and an experimental group, the investigators modified the study's design to follow a single group pretest-posttest quasi-experimental design (Portney and Watkins, 1993). The primary intention of the investigators remained the same; to measure the effects of eccentric exercise on the force output of the erector spinae using surface EMG. The investigators hoped to demonstrate this effect by comparing pretest and posttest measurements of the subjects following the exercise protocol. All subjects participating in this study now belonged to a single experimental group, and were required to participate in the exercise program. Subjects participated in an initial pretest to determine baseline values for their erector spinae force-output. Subjects then underwent a four-week, two-day a week eccentric training program for their erector spinae. The investigators gave each subject an assessment identical to the pretest at the end of the four week training program. Measurements obtained from subjects for the force output of their erector spinae at the end of the four weeks served as the posttest measurements.

Study Site and Subjects

Study Site

Investigators conducted the study in the therapeutic exercise laboratory of the Physical Therapy Department at Grand Valley State University (GVSU) located in Allendale, MI. Subjects reported to the laboratory for four weeks during February and March of 1998.
Subjects

Originally, 20 to 30 healthy, male and female subjects between the ages of 30 to 45 years old were to be solicited from a local Grand Rapids area organization/rotary club and from the students, faculty, and staff of GVSU. Researchers recruited subjects using convenience-sampling techniques by actively seeking volunteers on campus and at organizational meetings. Those volunteers who meet our inclusion criteria, and who had no exclusionary characteristics were accepted in this study. Exclusion and inclusion criteria are included in Appendix A. Investigators had subjects fill out a health status form to determine if patients met the study's criteria (Appendix B). Subjects signed an informed consent form prior to their participation in this study (Appendix B). Additionally, investigators performed a general orthopedic assessment of each subject's lumbar spine and lower extremities to screen for any major pathology. Researchers performed the orthopedic screen and its test in a manner consistent with that outlined by Magee, (1992). The data collection form for the orthopedic screen is located in Appendix D. Subjects had the right to stop participation at any time or for any reason during the four-week exercise and data collection period if they desired. After the screening process, the investigators had recruited only eight subjects; two males and six females, which met the inclusion/exclusion criteria and were willing to participate in the exercise routine.

Equipment and Instruments

Electromyography

Investigators used the Noraxon's Multichannel Myosoft/Myosystem 1200 EMG software system (Noraxon USA, Inc., 13430 North Scottsdale Road, Suite 104, Scottsdale, AZ 85254) to
collect and analyze the data during this study. Gordon Alderink, P.T., was consulted to assure that investigators knew how to properly apply the electrodes to acquire data. On-going monitoring was provided as needed. Researchers used a bipolar set-up involving four non-invasive, 4mm silver/silver chloride, surface electrodes. Prior to the electrode application, an investigator prepared the subject's by cleansing and abrading the application site with an alcohol wipe. If necessary, researchers removed excess hair with a disposable razor and wiped the area again with an alcohol wipe (Perry, Schmidt-Easterday, and Antonelli, 1981). For participant protection, the investigators provided each individual with a new razor and alcohol wipe each time needed.

Electrode Placement

Investigators used the Myosoft system to record EMG activity of the lumbar erector spinae muscles bilaterally at the level of the L3-L4 interspaces. Researchers placed the electrode approximately 3-cm lateral to the L3-L4 spinous processes at this level. Investigators separated the electrodes on each side by an approximate distance of 2.5 cm between the electrodes outer edges, superiorly to inferiorly. A researcher located the lumbar vertebral interspaces of each subject through palpation, using the iliac crest as a landmark (Ahern, Follick, Council, laser-Wolston, 1986). Additionally, the investigators placed a reference electrode over the sternum, to act as the ground electrode (Mannion and Dolan, 1996).
Procedure

Pretest and Posttest Protocol

All eight subjects participated in a pretest, before beginning the exercise program, in order to collect baseline data. The pretest consisted of surface EMG recordings of the subject's muscle activity during a maximal voluntary isometric contraction (MVIC) and while repeatedly lowering 120% of their concentric maximum, eccentrically. Researchers collected surface EMG data during the MVICs for use in the data normalization process. Investigators collected surface EMG data during the eccentric contractions at the initiation and termination of the study to determine strength increases in the erector spinae muscles during eccentric specific movements (Hortobagyi, Hill, Houmard, Fraser, Lambert, and Israel, 1996).

Investigators measured the maximal voluntary isometric contraction (MVIC) for each subject's bilateral erector spinae. To measure the MVIC of the erector spinae, the subjects lay prone on a plinth, with their arms at their sides. The subjects then arched their backs lifting their chests off the plinth, while an investigator applied manual resistance to the back of the shoulders (Vakos, Nitz, Threkeld, Shapiro, and Horn, 1994). Subjects held the contraction for three seconds while the EMG activity is recorded. Each subject repeated this contraction for a total of three times with a one-minute rest period in between.

Before the subjects could begin the eccentric exercise program, the investigators needed to determine the appropriate amount of resistance to be used for each subject. Researchers of prior eccentric strengthening programs have had the best results when using resistance equaling 120% of the subjects' concentric one repetition maximum (1RM). Investigators used the Oddvar Holten method described by Schwarcz (1997) to determine the resistance required constituting 120% of the subject's 1 RM. The Oddvar Holten curve, a table of repetitions and their percent of
the 1-RM, and a sample calculation of calculated training resistance are included in Appendix E. Researchers dosed the subjects for their appropriate exercise resistance by standing in a stabilization bench (described later). While stabilized in the bench, each subject bent forward and grasped a milk crate containing an amount of weight which the investigators had estimated to be less than or equal to the subject’s 1 RM. The subject performed repeated lumbar extension to neutral, lifting and lowering the weighted milk crate until fatigue. Researchers used the number of repetitions completed to determine the amount of weight needed to reach the subject’s concentric 1 RM.

After the appropriate resistance for each subject had been determined, the subjects performed 3 sets of 6 eccentric contractions while performing trunk forward flexion with lowering their specifically dosed amount of resistance. Subjects stood in an adjustable manual mobilization bench designed to support an erect person with their knees slightly bent on one bolster and with their hips stabilized anteriorly with another bolster (Appendix E). An investigator handed each subject a weighted milk crate (37 inches x 37 inches x 29 inches) representing a resistance equal to 120% of that subject’s concentric 1 RM, (Albert, 1995). The subject performed forward flexion of their trunk until they could set the milk crate on the floor. By completing this range of motion, the subject allowed for tension in their lumbar musculature to be transferred to its passive elastic structures and for the subsequent relaxation of the erector spinae to occur. As relaxation occurred, the EMG signal for the erector spinae was deadened, marking the end of the muscle contraction. The subject returned to standing and an investigator handed them the weighted milk crate. This was repeated for three sets of six repetitions. Subjects received a one minute rest period between sets (Albert, 1995). Subjects performed this procedure again at the end of the fourth week. Researchers collected EMG recordings during
each repetition of all three sets. Investigators averaged these values to determine the force output of the erector spinae during eccentric exercise at the beginning and the end of this study.

Exercise Protocol

Investigators positioned subjects for the eccentric exercise program in an identical manner to that used during the pre-test and post-test. Subjects performed the exercise program twice weekly, with a minimum of a one-day rest period in between, for four weeks. Researchers modified the protocol of Johnson et al. in which two sets of six reps were performed three days a week for six weeks. While the total amount of sets per week remained the same, subjects performed the same number of sets on fewer days to reduce the chance of delayed onset muscle soreness (DOMS), as recommended by Albert (1995). Investigators reassessed the subject’s 1 RM at the last exercise session of the second week, and additional weight was added as needed.

Additionally, all subjects participating in the exercise routine completed a five-minute warm-up period at a self-selected pace on a treadmill. Researchers had the subjects perform selected stretches for the lower extremities and lumbar spine before each exercise session (Appendix E). Each stretch was performed three times and held for 15 seconds. Investigators took these measures in order to further reduce the risk of DOMS.

Testing Procedure

As mentioned above, researchers collected data before and after the completion of the four-week exercise program for each subject. The data collection form is included in Appendix C. Investigators used surface EMG to record muscle activity during the three contractions assessing MVIC and during each repetition of the three eccentric exercise sets. The initiation
(beginning as the investigator said, "go") and termination (ending as the subject completed the appropriate range of motion) of each repetition was marked on the recording by the investigator. Researchers measured the force output for both the isometric (MVIC) and eccentric contractions using the mean signal amplitude obtained from each surface EMG signature.

**Data Analysis**

Investigators processed the surface EMG signal of each recorded contraction prior to data analysis. The data was collected with a sample frequency of 1000 Hz, and filtered at 250 Hz with a low pass Butterworth filter. The myosoft system first rectified the raw signal and then integrated it, before investigators determined the mean amplitude of each trial. After the raw signal was processed, the investigators converted the recording of each contraction's signature to an ASCI file. The ASCI file contained the exact microvoltage (μV) of each peak that occurred very time the EMG computer recorded a sample of the signal. At the sampling frequency of 1000 Hz, the computer recorded a sample of the EMG signal once per millisecond (mS). Investigators loaded each ASCI file onto a spreadsheet and the mean amplitude of each recording was determined. Only the signal recordings falling between the start and end time of each contraction as selected by the myosoft system software were used during the analysis. The eccentric data was normalized prior to data analysis. Normalization consisted of taking the mean of each subject’s pretest eccentric contractions divided by 100% of the mean pretest isometric contractions (MVIC). The same procedure was used in normalizing the posttest data. Data analysis for this study utilized the Wilcoxon signed rank test for paired sample, a non-parametric test. This test was used to compare the differences between the pretest and posttest treatment.
values for the mean amplitude of the subject's normalized eccentric contractions. The statistical significance level chosen for this study is $\alpha = .05$. This level was chosen as it is the standard level used in research by convention and is usually considered to have a "small enough" chance of committing a Type I error, while not being so small as to result in "too large a chance" of a Type II error (Zar, 1984).
Eight subjects, two men and six women, participated in this study. All subjects reported right-hand dominance, except for one left-handed female. The subjects had a mean age of 38, with an age range of 31-42 years. The subjects had a mean height of 67.25 inches with a range of 63-78 inches and a mean weight of 148 lbs. with a weight range of 112-210 lbs.

Researchers included only seven subjects in the analysis, after one subject’s initial data recordings were lost due to a computer usage error. As stated in Chapter Three, the Wilcoxon signed rank test for paired data was used to test the hypothesis of this study.

Tables 2 and 3 represent the raw mean amplitudes of the isometric and eccentric contractions for each subject before the data was combined during normalization. The mean of mean amplitudes for the three isometric contractions from the pretest and posttest of each subject is reported in Table 2. The mean of the mean amplitudes of the six eccentric contractions from the pretest and posttest of each subject is reported in Table 3.

The Wilcoxon signed rank analysis was used to test if the median of the differences between the pretest and posttest values of the normalized data was different from zero. First, the left and right normalized eccentric contractions were summed for each of the six trials and then the mean of the sums was computed. The differences between the pretest and posttest values for the normalized eccentric contractions (mean of the sum of left and right posttest values minus mean of the sum of the left and right pretest values) were analyzed. The results were
insignificant with a p-value = 0.2969. The Wilcoxon signed rank test was also used on the mean left and mean right normalized eccentric contractions separately. The results were also insignificant when the mean left and mean right were compared separately, p-values = 0.4688; 0.9375, respectively. For all three tests there is insufficient evidence at the .05 level to conclude that the median of the differences between the pretest and posttest measurements is different from zero. A report of descriptive statistics for each test is provided in Table 1.

Table 1
**Descriptive Statistics for Difference between Pretest and Posttest Measures**

<table>
<thead>
<tr>
<th>Test</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>-0.366</td>
<td>-0.242</td>
<td>1.131</td>
<td>-2.691</td>
<td>1.038</td>
<td>0.4688</td>
</tr>
<tr>
<td>Right</td>
<td>0.038</td>
<td>-0.068</td>
<td>0.291</td>
<td>-0.201</td>
<td>0.563</td>
<td>0.9375</td>
</tr>
<tr>
<td>Left + Right</td>
<td>-0.091</td>
<td>-0.143</td>
<td>0.460</td>
<td>-0.774</td>
<td>0.776</td>
<td>0.2969</td>
</tr>
</tbody>
</table>

Table 2
**Pretest Posttest Data of Raw MVIC Mean Amplitude (µV)**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pre Left</th>
<th>Pre Right</th>
<th>Post Left</th>
<th>Post Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject 1 f</td>
<td>95</td>
<td>87</td>
<td>106</td>
<td>106</td>
</tr>
<tr>
<td>Subject 2 f</td>
<td>70</td>
<td>87</td>
<td>113</td>
<td>97</td>
</tr>
<tr>
<td>Subject 3 f</td>
<td>108</td>
<td>93</td>
<td>186</td>
<td>69</td>
</tr>
<tr>
<td>Subject 4 f</td>
<td>19</td>
<td>67</td>
<td>200</td>
<td>154</td>
</tr>
<tr>
<td>Subject 5 f</td>
<td>343</td>
<td>291</td>
<td>316</td>
<td>231</td>
</tr>
<tr>
<td>Subject 6 m</td>
<td>289</td>
<td>271</td>
<td>255</td>
<td>219</td>
</tr>
<tr>
<td>Subject 7 m</td>
<td>195</td>
<td>245</td>
<td>176</td>
<td>172</td>
</tr>
</tbody>
</table>

* Females (f); Males (m)
Table 3
Pretest Posttest Data of Raw Eccentric Mean Amplitude (µV)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pretest L</th>
<th>Pretest R</th>
<th>Posttest L</th>
<th>Posttest R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject 1 f</td>
<td>62</td>
<td>55</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>Subject 2 f</td>
<td>85</td>
<td>116</td>
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<td>112</td>
</tr>
<tr>
<td>Subject 3 f</td>
<td>92</td>
<td>56</td>
<td>83</td>
<td>55</td>
</tr>
<tr>
<td>Subject 4 f</td>
<td>58</td>
<td>54</td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>Subject 5 f</td>
<td>27</td>
<td>62</td>
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<td>69</td>
</tr>
<tr>
<td>Subject 6 f</td>
<td>274</td>
<td>194</td>
<td>159</td>
<td>122</td>
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<tr>
<td>Subject 7 m</td>
<td>132</td>
<td>110</td>
<td>114</td>
<td>83</td>
</tr>
<tr>
<td>Subject 8 m</td>
<td>84</td>
<td>88</td>
<td>214</td>
<td>176</td>
</tr>
</tbody>
</table>

* Female (f); Male (m)
Chapter 5
Discussion

Interpretation of Statistical Outcomes

The purpose of this study was to determine if the force output of the erector spinae would be significantly different between the pretest and posttest measurements following an eccentric strengthening protocol. Changes in force output were estimated using the surface EMG mean amplitude of both the pretest and posttest measurement of the normalized eccentric contractions. Statistical analysis failed to support such a difference. We do not have evidence to determine whether or not an eccentric strengthening protocol is a significant factor in the increase of mean amplitude of surface EMG recordings of eccentric contractions. However, as shown in the following section, eccentric exercise may have provided a beneficial factor, which was not statistically observable from the initial analysis.

This possible benefit is suggested for two reasons. The first is the increase in resistance used for each subject from initial dosing to the second dosing. Subjects showed a mean increase of 10.75 kilograms, with a range of 4-30 kilograms (table 4). The cause of the increase in resistance used may be attributed to factors other than an increase in erector spinae strength; these factors are discussed in our limitations section. Second, during observation of the raw data for the MVIC contractions, changes were seen in force output when the subjects were grouped according to subjective fitness levels. This observation may indicate interesting trends which may lead to significant findings with further study.
Table 4  
Resistive Loads (kg)

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pretest Load</th>
<th>Posttest Load</th>
<th>Difference (Post-Pre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject 1 f</td>
<td>30</td>
<td>39</td>
<td>9</td>
</tr>
<tr>
<td>Subject 2 f</td>
<td>37</td>
<td>49</td>
<td>12</td>
</tr>
<tr>
<td>Subject 3 f</td>
<td>13</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>Subject 4 f</td>
<td>29</td>
<td>38</td>
<td>9</td>
</tr>
<tr>
<td>Subject 5 f</td>
<td>20</td>
<td>27</td>
<td>7</td>
</tr>
<tr>
<td>Subject 6 f</td>
<td>25</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>Subject 7 m</td>
<td>78</td>
<td>84</td>
<td>10</td>
</tr>
<tr>
<td>Subject 8 m</td>
<td>51</td>
<td>81</td>
<td>30</td>
</tr>
</tbody>
</table>

Discussion of Results

The Wilcoxon Eccentric Results

Analysis of the eccentric data sets using the Wilcoxon signed rank test for paired data provided no evidence to support the researchers’ hypothesis that an eccentric exercise protocol could increase the force output of the lumbar erector spinae. Researchers recognize two reasons for the lack of evidence for their initial hypothesis. One reason may be that the relationship explored does not exist in nature. This possibility is discussed and compared to other research findings in the following section. Another reason for lack of evidence to support the hypothesis, based on the Wilcoxon comparison, may stem from flaws in the study’s design. These limitations are also discussed in a later section.
Observation of Raw Data

As stated previously, certain trends in the raw data of the MVIC contractions prompted the researchers to re-group the subjects according to level of subjective fitness. A table of the left and right mean EMG amplitude for the mean of the MVIC contractions and mean of the eccentric contractions of each subject is reported in Appendix F, figures 1 and 2. Although all subjects selected for this study were healthy, a specific fitness level was not determined. Subjects were considered to be physically “fit” based on a subjective description by the investigators as an overall level of condition attributed to a lifetime of regular to heavy exercise. Three subjects in this study can then be subjectively selected into the “fit” category. The observation of raw data for this group showed a decrease in erector spinae force output. However, the subjects showing an increase in erector spinae MVIC force output were those who do not participate in specific regular exercise routines. As seen in figure 3 (Appendix F), overall increases and decreases in the “fit” and “unfit” group were expressed in terms of the combined mean left and right mean amplitude for all members of each group for the pretest and posttest data. There may be several factors as to why persons experience either an increase or decrease in force output. How this may relate to each “fit” or “unfit” subject group is unclear and may not result from physiological changes but rather from the limitations of this study.

Comparison with Similar Research Findings

Eccentric Contraction Research

While the present study fails to provide evidence to support the hypothesis that eccentric exercise can increase the force output of the lumbar erector spinae as measured by the associated surface EMG amplitude, other research suggests that this relationship may exist for other muscle
groups. The majority of this research supports evidence to suggest that surface EMG amplitude is positively related to muscle force-output (Sale, 1988) and that muscle force output will increase after performing a progressive resistance exercise (PRE) program for an appropriate amount of time (McArdle, Katch, and Katch, 1996).

The findings of this current study, which increases in EMG activity did not significantly increase with eccentric training, are in contradiction to other research investigated in this study. Researchers concluded there was insufficient evidence to suggest that there was a significant difference between the pretest and posttest strength of the erector spinae as measured by associated EMG output. Hortobagy, Hill, Houmard, Fraser, Lambert, and Israel concluded that following an eccentric strengthening protocol eccentric force output had increase by 116% and surface EMG activity during eccentric contractions increased by 188% (1996). Sale cites a 1986 study by Komi and Buskirk concluding that after a training period involving drop-jumping, a trained jumper responded with a period of increased EMG activity facilitation during the eccentric phase, whereas untrained jumpers did not (1988). Taking into account the results of other literature, it may be suggested that perhaps it was the limitations of the study (to be described later) which contributed to the lack of evidence, rather then the absence of the hypothesized physiological phenomenon.

Delayed Onset Muscle Soreness (DOMS) Outcomes

As an interesting note, none of the subjects at any time during the experiment experienced DOMS in their lower back. Two subjects complained of calf and hamstring soreness or upper body/arms soreness after one or two sessions. This soreness was not significant and the subjects were able to continue. These results are in contrast to other eccentric
research. DOMS is typically observed with eccentric exercise (Golden and Dudley, 1992),
(Balnave, Thmpson, 1993), (Newham, Jones, and Clarkson, 1987), (Bell, and Wenger, 1992).
Reasons DOMS may not have occurred in the present study may be due to two reasons. One
reason is that the selected exercise movement incorporates many muscle groups which may have
been primarily used in synergy with the erector spinae for the lowering tasks (Lavender, Tsuang,
and Anderson, 1994). It is possible that the selected exercise was really strengthening these
associated muscle groups more preferentially then the erector spinae. Increases in strength of
these associated muscle groups may also have accounted for the increased amount of resistance
used by all subjects after the second dosing, rather then increased strength in the erector spinae
themselves. A second reason that DOMS was not experienced could be that the damage
associated with type II fibers during eccentric exercise may not have been noticeable due to the
small number of type II muscle fibers in the erector spinae (Rantanen, et al., 1994),
(Thorstensson, and Carlson, 1987), (Sirca, 1985).

Limitations

Study Design

There were several limitations to this study, which may have influenced the outcome,
some resulting from the study’s design. Perhaps the most significant faults of the study’s design
were the lack of a control group, absence of stricter guidelines on the inclusion/exclusion criteria,
the length of exercise protocol, and the small sample size. The addition of a comparison group
would have helped to eliminate external variables. Additionally, the activity level of the
participants could have been more rigidly defined. Traditional strengthening protocols have
shown better results after a minimum of six to twelve weeks of subject participation in the
training protocols. The small sample size of the existing experimental group, limited the power of the statistical tests applied to determine differences in the pretest and posttest groups.

Monitoring of subject activities during the experiment needed stricter regulation. The subjects were asked during the initial evaluation for the pretest, to refrain from their typical exercise routine during their participation in this study. During the course of the study, the researchers found that subject compliance with this restriction was low. Extracurricular activities included; chopping wood, shoveling snow, playing basketball, swimming and running. Data collection for each subject should also have been performed at a consistent time of day. This would have avoided the effect of variability of time of day on the muscular strength of the subjects (Sinaki & Offord, 1988).

Test Instruments/Testing Procedure

One reason investigators selected surface EMG as the instrument of data collection for strength measurement was that it could give an indication of what changes were occurring in a specific muscle group, in our case the lumbar erector spinae, versus other methods which measure the total contribution of all muscles which act in a specific movement. As studies have shown, EMG is useful in estimating indirect improvements in force output (muscle strength) only, and not for providing for a direct measurement of that force output (Vakos, Nitz, Threlkeld, Shapiro, and Horn 1994). Cable Tensiometry and Dynamometry have been proven to be reliable and valid ways of precisely measuring the maximum tension generated by a single muscle, such as the bicep, or group of muscles (McArdle, Katch and Katch, 1995). In this study, investigators wanted to investigate the change in strength of the lumbar erector spinae specifically. Had tensiometry or dynamometry been selected, only a general indication of the change in strength of
all muscle groups contributing to static lumbar extension (MVIC) or eccentric lengthening could have been obtained. In this study direct strength measurement of all muscle groups contributing to a specific motion was sacrificed for an estimation of strength pertaining to one specific muscle group. Perhaps the addition of an instrument, such as a dynamometer or a tensiometer, could have been included for use in study. This instrument would provide comparison of a direct measure of total muscle strength contributing to a particular motion to the force estimation by the activity of one specific muscle group participating in that motion. Investigators had included the 1-RM which is also useful in measuring the maximum force or tension generated by a muscle or group of muscles (McArdle, Katch and Katch, 1996). However, the investigators only took 1-RM measurements at the onset and midway through the training program. Had the investigators included a final 1-RM dosing at the termination of the exercise program, they may have better able to demonstrate an overall increase in muscular strength.

Another possible limitation is the method by which isometric strength was tested. Other studies have used a similar method as the investigators to test isometric strength; the use of manual resistance applied by the investigator to the subject’s upper torso as they try to extend their backs. This method may be subject to variability if the investigator does not use equivalent force each time the subject is tested, or the if the subjects ability to extend supersedes the investigator’s ability to apply resistance downward. Perhaps a better method of testing isometric strength is having the subject contract their erector spinae against an immovable back pad, such as those used in isokinetic testing (Mooney, et al., 1997) or an immovable force plate (Sinaki and Offord, 1988).

Because of the nature of the functional lowering task, it was difficult to design an exercise that would eccentrically train the erector spinae only, while eliminating the contribution
of other muscle groups. In order to do this, resistance would have been attached to the torso by some sort of harness, or weighted backpack which could be lowered through the entire range without the use of the arms or lower extremities. While this type of orientation was not feasible for this study it can be argued that during everyday function, other muscle groups would act in conjunction with the erector spinae. The muscle groups include postural set muscles, lower extremity muscles, and abdominal muscles involved in abdominal bracing. Although the subjects in this study did not experience any DOMS or trauma, a safer procedure for eccentric strengthening could also be developed.

Additionally, the study could have been better controlled if the timing of contractions and duration of rest periods had been strictly monitored by the researchers. Every subject should have lowered the weight at a constant interval as well as maintained accurately timed rest periods. Prior researchers have all used constant interval of three or four seconds as an appropriate time of an eccentric contraction (Hakkinen & Komi, 1983), particularly when moving through a range of motion of 90 degrees (Johnson, Adamczyk, Tennoe, and Stromme, 1976). Investigators failed to accurately control for a consistent number of days between exercise sessions. Although DOMS was not a factor in this study, Albert suggests a rest period of 72 hours between session to eliminate the effects of DOMS typically associated with eccentric training (1995). The authors of this study attempted to schedule subjects within this parameter, however, this could not always be maintained.
Clinical Significance

As yet, this study does not lend itself to direct clinical application. Because of the potential benefits of eccentric contractions, exercise specificity, and the unique morphology of the erector spinae, there may still be implications to develop rehabilitative functional lowering tasks. As this study is unique in the field of eccentrics and low back research, further investigation may be beneficial in determining if there are grounds for clinical use.

Further Research

The outcomes of this study point to several areas of further research. The most significant would be a controlled study comparing physically conditioned to unconditioned subjects. Functional benefits should be determined along with the development of a treatment program that safely utilizes eccentric exercise in a low back rehabilitation program. The functional lowering task itself may also be investigated to control for upper body muscle activation and compensation by the lower extremity muscle groups. In all further research, a careful control for the limitations sited in this study is urged to ensure accurate findings.

Conclusion

The major results from this study are inconclusive in determining if there is any strengthening effect from eccentric training on erector spinae. As discussed in the limitations of this study, major variables to be considered are: specific fitness level, longer length of study, increased number of subjects, use of a control group, and refinement of the eccentric exercise to have some clinical carryover.
Appendix A

Inclusion Criteria:

1. Individual is 30 to 45 years old.
2. Individual has signed the informed consent form.
3. Individual states that they are currently in excellent health.
4. Individual is currently not performing a daily resistive exercise routine.

Exclusion Criteria:

1. Individual has refused to sign informed consent form.
2. Individual has a medical history which includes stroke, heart disease, angina (either controlled or uncontrolled), or hypertension.
3. Individual has a medical history which includes diabetes or other chronic condition which may compromise their health.
4. Individual has a medical history of back pain, strain, arthritis, or trauma to the lower back or its musculature within the last year.
5. Individual has had spinal surgery.
6. Individual is pregnant.
7. Individual is currently involved in a daily resistive exercise routine.
Appendix B

Informed Consent Form

I understand that this is a research project conducted by physical therapy students from Grand Valley State University. The project's investigators have designed this study to determine the effects of an eccentric strengthening program on the erector spinae muscle group of the lumbar spine. Results of this study will add to our current knowledge, which may help physical therapists and other health professionals find better ways to increase the strength and functional abilities of individuals suffering from low back problems. I have been selected to participate in this study on the basis of my current good health status and my age.

I also understand that:

1. I will participate in one of two groups, a control group used for comparison, or an exercise group. The force output of my low back musculature will be measured using EMG at the beginning, at midterm (exercise group only), and at the end of the study.

2. If I have been selected to participate in the control group, I will resume my normal activities of daily living during the four-week period between measurement.

3. If I have been selected to participate in the exercise group I will participate in the exercise program twice weekly, for four weeks, with each session lasting approximately 30 minutes.

4. I have read and signed the Health Status Form and have had a general back screen performed by the investigators. I have been informed that I may experience some muscle discomfort or temporary soreness during the four week training activities. This soreness is brought on by my participation in activities not commonly performed in my daily activities. The soreness should peak after 48-72 hours after exercise, and should decrease as the study progresses. If it doesn’t, I should contact Christopher Moore at (616) 667-1005 or Audi Chenoweth at (616) 735-0705, and I will be treated as described in the Health Status Form.

5. My confidentiality will be protected to the extent permitted by law. My name will not be revealed in any report or publication resulting from this study without my express written consent.

6. A summary of the results will be made available to me upon request.

I confirm that:

1. I have been given an opportunity to ask questions regarding this research study, and that these questions have been answered to my satisfaction.
2. In giving my consent, I understand that my participation is voluntary and that I may withdraw from the study at anytime by contacting Audi Chenoweth at (616) 735-0705 or Christopher Moore (616) 667-1005. If I decide not to participate in this study there will be no consequence as a result of my leaving the study.

3. I am willing to release the information obtained in this study to the scientific literature.

4. I understand that by my agreement to participate in this study I am not waiving any legal rights.

5. I understand that if I have any additional questions or concerns I may contact Barb Baker, P.T., Advisory Committee Chairperson at (616) 895-2676, Dan Vaughn, P.T., Advisory Committee member at (616) 895-2678, Justine Ritchie, Advisory Committee member at (616) 895-2055, or Paul Huizenga, GVSU Human Subjects Review Committee Chairperson at (616) 895-2472.

I HAVE READ AND UNDERSTOOD THE ABOVE INFORMATION AND AGREE TO PARTICIPATE IN THIS STUDY.

Participant's signature: ____________________________  Date: ____________

Witness' signature: ________________________________  Date: ____________
Health Status Form

I hereby state that based upon my self-perception and upon my last physician’s visit or yearly physical, I am currently in good health. Furthermore, I state that my current health status meets the following conditions:

1. I have not been diagnosed with any of the following cardiovascular conditions; angina (controlled or uncontrolled), heart disease, hypertension, or stroke

2. I have not been diagnosed with any of the following; diabetes mellitus, osteoarthritis, osteoporosis, rheumatoid arthritis, or other chronic condition, which may compromise my health.

3. I have not suffered any back pain, strain, arthritis, or trauma to my lower back or its musculature within the last year.

4. I have not had any spinal surgery.

5. I currently am not pregnant, nor do I expect to become pregnant in the next four weeks.

I understand that the researchers in this study have included in the study’s design, several measures, which will decrease the likelihood of personal injury to individuals participating in this study. These measures included:

1. Pre-assessment and orthopedic screen of my lumbar spine and lower extremities

2. Individually dosed resistance to meet participant’s abilities.

3. A stretching program specific to the lumbar spine and a 5 minute warm-up routine, prior to each exercise session.

4. Rest periods between each set during each exercise session, and at least a full 2 days rest between each exercise session for recovery.

I have been informed that despite these precautionary measures, some individuals may experience muscle soreness, which may last beyond the expected 48-72 hours. In the event that I am one of these individuals, I will be removed from the study, to prevent further discomfort. My condition will be monitored and I will be evaluated by a licensed physical therapist from Grand Valley’s State University’s Physical Therapy program.

Participant’s Name: _________________________________ Date: ___________
Witness’s Name: _________________________________ Date: ___________
Appendix C

Data Collection Form

Name: Initial Midterm Final

Dosing Exercise:

Concentric Contractions: Repetitions: _________ Weight: _______

MVIC:
1. _______ 2. _______ 3. _______

Eccentric Contractions:

Mean Peak:

Left: Right:

1. _______ 2. _______ 3. _______ 4. _______
5. _______ 6. _______
Appendix D

Orthopedic Screen

PATIENT INFORMATION:

Name:  
Height:  
Weight:  
Sex:  
Age:  

ORTHOPEDIC SCREEN:

LUMBAR SPINE ROM:

Forward Flexion:  
Extension:  
Lateral Flexion: Left:  
Rotation: Left:  
Right:  
SPECIAL TESTS:

Quadrant test: Left:  
Compression:  
Leg length discrepancy:  
Slump test:  
Straight leg raise: Left:  
Scouring test (hip): Left:  
Right:  
LOWER EXTREMITIES (MMT):

Hip Flexion: Left:  
Knee Extension: Left:  
Ankle Dorsiflexion: Left:  
Knee Flexion: Left:  
Right:  
Quick test (Squat):
Appendix E

Stretches

1. Lower Back – Double Knee to Chest
2. Lower Back – Hamstring Stretch
3. Stabilization Bench
4. Oddvar Holten Curve (Schwarcz, 1997)
5. Table of Percent of 1 RM (Schwarcz, 1997)
6. Sample Calculation of Resistance Dosing
HOME EXERCISES

Lower Back — Flexion Exercise

Double Knee to Chest

1. Lie on your back.
2. Using both hands, grasp your right leg behind the knee and pull your knee to your chest.
3. Keeping your right knee up, repeat the procedure for your left knee.
4. Hold for five seconds and relax.
5. Lower your right leg, then your left leg.

Repeat ______ times

Special Instructions
HOME EXERCISES

Lower Back — Flexibility Exercise

Hamstring Stretch II

1. Lie on your back with a pillow under your head.
2. Grasp one knee from behind with both hands, and pull it toward your chest.
3. Straighten your leg to the point of tightness.
4. Hold for 10 seconds and relax.

Repeat _______ times

Special Instructions
Oddvar Holten Diagram

---

<table>
<thead>
<tr>
<th>Percent of 1 R.M.</th>
<th>Strength</th>
<th>Power</th>
<th>Strength/Endurance</th>
<th>Endurance</th>
</tr>
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<tbody>
<tr>
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<tr>
<td>60%</td>
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<td></td>
</tr>
<tr>
<td>65%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70%</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>75%</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>80%</td>
<td></td>
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<tr>
<td>100%</td>
<td>1 Rep.</td>
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**RM:** Resistance Maximum: the amount of weight that can be overcome one time.


**Exercise with 30 repetitions at 60% of 1RM causes an increase in blood flow to the muscle.**

**Strength gains begin at 47% of 1 RM.**


**Calculation of RM & Amount of Weight to Exercise With:**

1. For the selected exercise and weight, determine the maximum number of reps that the patient can perform without producing pain or increasing their pain.
2. Find the percentage of RM on the above graph that corresponds with the number of reps completed by the patient for the given exercise.
3. Divide the amount of weight used in the given exercise by the percentage of RM found in step #2. This equals the weight for 1 RM.
4. To determine the amount of weight to exercise with multiply the calculated 1 RM weight by the RM percentage that corresponds with the number of reps the patient is to performed.
5. In order to perform 3 sets of the same exercise subtract 15 to 20% from the number of reps selected in #4 above.
Table 1: PERCENT OF 1 RM

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Sample Calculation of Resistance Dosing

Subject completes 10 repetitions with 30 kg (repeatedly lifting and lowering to exhaustion):

10 repetitions equals 82% of the Subject’s 1-RM

30 kg x 120% of 1-RM (used for eccentric contractions)
82% of 1-RM

43 kg equals the resistive load required to provide 120% of subject’s 1-RM
Stabilization Bench
Appendix F

Figures

1. Mean of the left and right mean amplitude of the MVIC contractions for the pretest and posttest of each subject (before normalization)

2. Mean of the left and right mean amplitude of the eccentric contractions for the pretest and posttest of each subject (before normalization)

3. Trends in the pretest and posttest MVIC data, (before normalization) representing the mean value of all the members in the “fit” and “unfit” groups
Fit versus Non-fit

- Fit
- Non-Fit

Pre Post
Bibliography


Deluca, C.J. (1993). *Surface electromyography: Detection and recording,*


Nardone, Romano. (1988). Selective recruitment of high threshold human motor units during voluntary isotonic lengthening of active muscles,


