1-1-1995

The effect of hip position and Emg biofeedback training on selectively increasing the vastus medialis oblique in relation to the vastus lateralis

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THE EFFECT OF HIP POSITION AND EMG BIOFEEDBACK TRAINING ON SELECTIVELY INCREASING THE VASTUS MEDIALIS OBLIQUE IN RELATION TO THE VASTUS LATERALIS

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of

Master of Science

in

Kinesiology

Department of Kinesiology
University of Nevada, Las Vegas
May, 1996

UMI Number: 1380502

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May, 1996

ABSTRACT

Patellofemoral Pain Syndrome (PFPS) is a patellar tracking dysfunction usually associated with a muscular imbalance between the vastus medialis oblique (VMO) muscle and vastus lateralis (VL) muscle. The imbalance is most commonly attributed to a weak VMO resulting in a smaller VMO:VL ratio. Several electromyographic (EMG) studies have defined specific limb positions (such as external rotation of the hip) that preferentially activate the VMO. However, there has been no literature to show that preferential activation of the VMO successfully translates into increased VMO:VL ratios with training. The purpose of this study was to investigate the effects of hip rotation on the mean VMO:VL EMG ratio using EMG biofeedback over a 5 day training period. Thirty-six healthy female college students performed isometric quadriceps contractions, in terminal extension, with one of three hip positions: external hip rotation, internal hip rotation, and the anatomically neutral position. All participants were able to increase their VMO:VL ratio in 5 days regardless of hip position. Furthermore, external rotation of the hip was found to be a more effective position for the modification of the VMO:VL ratio than internal hip rotation. Exercises that incorporate external rotation of the hip, therefore, may be advisable in the treatment of PFPS.

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ACKNOWLEDGMENTS

I would like to thank my family and friends for their support and encouragement. The completion of this thesis would not have been possible without it. I would also like to express my sincere gratitude to Dr. Bill Holcomb, whose advise and help were very valuable to me. I would also like to thank my college committee members Dr. Mark Guadagnoli, and Dr. Richard Tandy. In addition, I would like to thank Dr. Susan Pero for her help with my thesis. I would like to express my appreciation to my fellow graduate assistants, Cris Becker, Jutta Denenna, and Kami Prince for their support and assistance in data collection. Finally, I would like to thank Dr. Cram at Clinical Resources for generously providing the Electromyographic Biofeedback unit.

CHAPTER 1

INTRODUCTION

Patellofemoral Pain Syndrome (PFPS) is one of the most frequent knee pathologies seen in orthopedic practice (DeHaven & Littner, 1986; Fox, 1975; Malek & Mangine, 1981; Steadman, 1979). With PFPS the patella is unable to correctly track in the femoral groove resulting in anterior knee pain (Wise, Fiebert, & Kates, 1984). This disorder is commonly caused by muscular imbalance (Ficat & Hungerford, 1977; Insall, 1982; Kramer, 1986; Lieb & Perry, 1968; McConnell, 1986) and malalignment of the knee extensor mechanism (Ficat & Hungerford, 1977; Insall, 1982; McConnell, 1986). Both causes are associated with vastus medialis oblique (VMO) deficiency as compared to the vastus lateralis (VL).

The relationship between the strength of the VMO and the VL is directly related to PFPS. The VMO and VL determine the pull of the patella in the femoral groove. PFPS patients typically exhibit a marked decrease in VMO activity thus decreasing the ability of the VMO to produce medial patellar tracking to counteract the lateral forces produced by the VL. Increasing the VMO:VL ratio improves patellar tracking thus decreasing the symptoms of PFPS (Wise et al., 1984). For this reason, reestablishing the VMO - VL balance is the primary goal of PFPS rehabilitation programs.

Improving the VMO:VL ratio can be accomplished by selectively training the VMO to increase its activity in relation to the VL. Numerous researchers have suggested manipulating the position of the lower limb to facilitate preferential activation of the VMO, therefore increasing the effectiveness of the therapeutic exercise (e.g., McConnell, 1986). One commonly suggested limb position is hip external rotation. Wheatley & Jahnke (1951) found that external rotation of the hip significantly increased VMO electromyographic (EMG) activity. This is supported by anatomical and biomechanical studies that have shown a functional link between the VMO and the adductor magnus muscle. Because the VMO partially originates from the adductor magnus muscle which assists external rotation of the hip (Antich & Brewster, 1986; Bose, Kasnagasuntheram, & Osman, 1980; Brownstein, Lamb, & Mangine, 1985), concurrent activation of the adductor magnus and the quadriceps should facilitate activation of the VMO (Karst & Jewett, 1993; Reynolds, Levin, Medeiros, Alder, & Hallum; 1983). However, more recent studies by Wild, Franklin, and Woods (1982), and Cerny (1995) have found that the activity of the VMO is not significantly enhanced by externally rotating the hip. It is unclear why the findings differ. Thus, some controversy still exists as to whether the use of hip external rotation increases VMO activity.

Increasing VMO activity while maintaining or decreasing VL activity is a difficult task which is nearly impossible to accomplish without specialized training. EMG biofeedback has been shown to be an effective means to provide the specialized training needed to achieve enhanced control over the VMO and VL (LeVeau & Rogers, 1980). During muscle contraction, EMG

instrumentation monitors and provides feedback as to the magnitude of motor unit recruitment in the VMO and VL. This feedback increases the level of awareness over the physiological processes taking place. It also assists the development of voluntary control over the individual muscles by confirming and reinforcing the fact that the desired motor response was made (Draper, 1990). Thus, individuals may learn to use the near real time signals to manipulate and change their VMO:VL activity levels.

Statement of the Problem

The primary goal in conservative PFPS rehabilitation programs is to improve the VMO:VL ratio by selectively increasing the activity of the VMO. Wheatley & Jahnke (1951) found that external hip rotation increased EMG activity in the VMO. They also found that internal hip rotation increased VL EMG activity. However, more recent EMG studies have not supported these findings (Cerny, 1995; Karst & Jewett, 1993; Wild et al., 1982). Therefore, it is currently under debate as to whether external rotation of the hip can significantly increase VMO activity.

Many researchers have suggested coupling a limb position that increases VMO activity with therapeutic exercise as a means of increasing the VMO:VL ratio (e.g., McConnell, 1986). It is presumed that preferential activation of the VMO during EMG studies will translate into increased VMO:VL ratios with training, although this transition has not yet been investigated. If VMO activity does increase during external hip rotation, it is logical to presume that training the VMO in this position would produce greater increases in the VMO:VL ratio than training with the hip internally rotated (the position shown to increase VL activity). Therefore, the following

study was designed to test the effect of hip position on the ability to increase the VMO:VL ratio during training with EMG biofeedback.

Purpose of the Study

Many researchers have speculated that selectively training the VMO in external hip rotation will increase the VMO:VL ratio to a greater extent than training with the hip internally rotated or in the anatomically neutral position. This is based on anatomical, biomechanical, and EMG studies that suggest that the VMO is preferentially activated when the hip is laterally rotated. Therefore, the purpose of this study is to determine if external rotation of the hip is a more effective position for the purpose of increasing the VMO:VL ratio when compared to the other two noted positions. A further purpose of this investigation is to provide evidence that may support the clinical use of EMG biofeedback in the treatment of PFPS.

Need for the Study

PFPS is one of the most common pathologies affecting the knee. Therefore, an effective and efficient treatment protocol is desired. Identification of specific exercises designed to selectively enhance the VMO would increase the effectiveness of PFPS rehabilitation programs. Although EMG, anatomical, and biomechanical studies have suggested hip external rotation as a means to increase VMO EMG activity, it is unknown whether the preferential activation of the VMO during EMG studies will translate into improved VMO:VL ratios with training.

Hypothesis

In several cases it has been demonstrated in previous literature that EMG activity increases in the VMO when the hip is externally rotated while

internal rotation of the hip produces the highest levels of EMG activity in the VL (Wheatley & Jahnke, 1951). However, more recent EMG studies have not supported these findings (Cerny, 1995; Karst & Jewett, 1993; Wild et al., 1982). Therefore, one hypothesis is that an EMG biofeedback program executed in external hip rotation will increase the VMO:VL ratio more than a program executed in either internal hip rotation or an anatomically neutral position. The other hypothesis is that hip position will have no effect on increasing the VMO:VL ratio.

Limitations

Participants used in this study had asymptomatic knees with no known musculoskeletal dysfunction. Further investigation using participants with patellofemoral dysfunctions would be necessary before interpreting the data for use with PFPS patients. The use of surface electrodes to assess muscular activity has some inherent limitations in a test-retest protocol. Although precautions were taken to ensure electrode locations were duplicated each session, a variation in the site can cause an increase or decrease in electrode impedance resulting in an unwanted alteration of the VMO:VL ratio. Other limitations include the size of each group (12 participants) and the single gender composition (female) of each group. Hence, the results of this study should be viewed with these potential confounding variables in mind.

CHAPTER 2

REVIEW OF LITERATURE

Patellofemoral Pain Syndrome

Complications or dysfunctions of the patellofemoral joint develop often and are indicated as one of the most frequent knee pathologies seen in orthopedic practice (DeHaven & Littner, 1986; Fox, 1975; Malek & Mangine, 1981; Shelton & Thigpen, 1991; Steadman, 1979). Patellofemoral Pain Syndrome (PFPS) most commonly describes knee pathologies in which, anterior knee pain is a symptom (Wise, Fiebert, & Kates, 1984), the patella's ability to correctly track in the femoral groove is compromised, and the patella's articular cartilage is not damaged (Malek & Mangine, 1981). It is accepted by many researchers that malalignment of the patellofemoral joint is the underlying etiology of PFPS (Ficat & Hungerford, 1977; Fox, 1975; Insall, 1982; Kramer, 1986; Wise et al., 1984). This malalignment may be produced by abnormal anatomical architecture (Ficat & Hungerford, 1977; Insall, 1982; Kramer, 1986), quadriceps extensor mechanism malalignment (Ficat & Hungerford, 1977; Insall, 1982; McConnell, 1986), muscular imbalance (Ficat & Hungerford, 1977; Insall, 1982; Kramer, 1986; Lieb & Perry, 1968; McConnell, 1986), or abnormalities in the retinacular restraints (Insall, 1982; Kramer, 1986; McConnell, 1986).

The patella lies within the tendon of the quadriceps muscles (Figure 2). This functions to increase the knee's mechanical advantage by increasing the quadriceps lever arm (Ficat & Hungerford, 1977). For the extensor mechanism of the knee to function properly the patella must track correctly in the femoral groove (McConnell, 1986). Patellar tracking is affected by passive forces (bony structures, connective tissues, and inactive muscles), and active forces (forces that occur when the contractile mechanisms of the tendons attached to the patella are activated by the nervous system) (Figure 1 & 4). These forces tend to displace the patella medially or laterally during knee flexion and extension. The active forces most responsible for patellar tracking are the VMO and the VL (Figure 3). An imbalance of these forces, particularly when lateral forces exceed the medial forces on the patella, cause Patellofemoral Pain Syndrome (Karst & Jewett, 1995).

Because of its anatomical position, the VMO is directly responsible for the correct alignment of the extensor mechanism of the knee (LeVeau & Rodgers, 1980) and for patellar tracking (Lieb & Perry, 1968). The VMO originates on the medial aspect of the distal femur and inserts directly into the medial side of the patella (Lefebvre, Leroux, Poumarat, Vanneville, & Boucher, 1994; Wise et al., 1984). These fibers insert at an average angle of 50-55° with the long axis of the femur and work to counteract lateral shifting of the patella by producing medial tracking (Basmajian & DeLuca, 1985; Lefebvre et al., 1994; Lieb & Perry, 1968; Malek & Mangine, 1981; Wise et al., 1984). Therefore, the VMO is considered to be the primary active stabilizer of the patella and is responsible for maintaining the patella's position in the femoral groove (Malek & Mangine, 1981; Wise et al., 1984) .

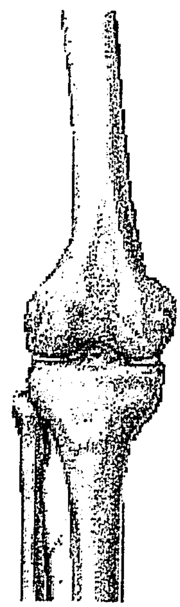

Figure 1: Right Knee Structure

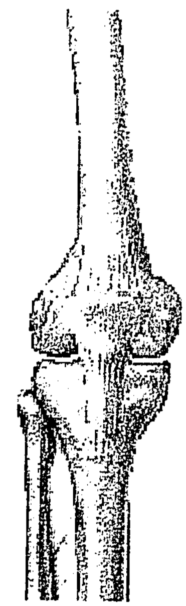

Figure 2: Placement of Patella

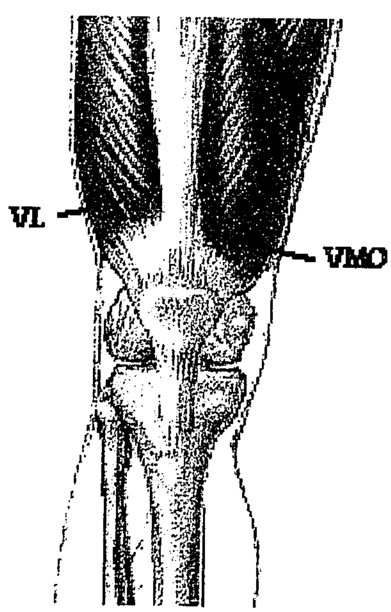

Figure 3: VMO & VL Placement

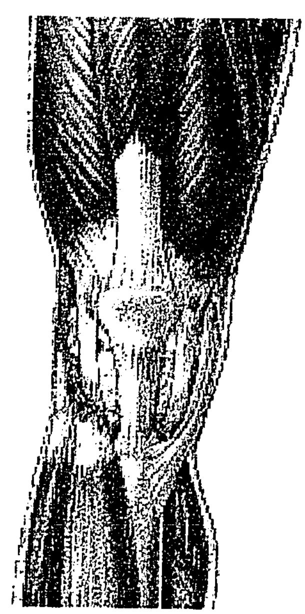

Figure 4: Related Knee Structures

Vastus Medialis Oblique (VMO) Insufficiency

Researchers have found that patellofemoral pain is associated with VMO muscle hypotonia (Antich & Brewster, 1985), and notable VMO atrophy (Hanten & Schulthies, 1990; Mariani & Caruso, 1979; Reynolds et al., 1983). Previous research has also shown a relationship between VMO:VL activity ratio and PFPS. Souza and Gross (1991) found that normal subjects have VMO:VL electromyographic (EMG) ratios significantly greater than the VMO:VL EMG ratios of subjects with PFPS. In a study by Mariani and Caruso (1979), subjects with patellofemoral pathologies were found to have smaller EMG levels for the VMO in relation to the VL in terminal extension. In addition, Boucher, King, Lefebvre, & Pepin (1992) found that subjects with PFPS had smaller VMO:VL ratio at 15°, 30°, and 90°. However, healthy subjects had equal EMG activity levels for the VMO and VL in both studies (Boucher et al., 1992; Mariani & Caruso, 1979).

Because the VMO and VL function together to align the patella, disruption of the muscular balance can significantly affect patellar alignment (Ficat & Hungerford, 1977; Lieb & Perry, 1968). Therefore, reestablishing or maintaining this balance is important. Modifying the VMO:VL EMG ratios will improve patellar tracking and thus decrease the symptoms of PFPS (Wise et al., 1984).

Selectively Training the VMO

Several researchers have suggested selectively strengthening the VMO to correct the imbalance with the VL that is associated with PFPS (Brownstein et al., 1985; Fox, 1975; Insall, 1982; LeVeau & Rogers, 1980; Levine, 1979; Lieb & Perry, 1971; Wise et al., 1984). In order for this method of rehabilitation to be

effective, anatomical and biomechanical factors must be considered, such as when the VMO is most active, and what exercises can be performed pain free by the PFPS patient.

Isometric contractions of the quadriceps muscles with the knee in terminal extension are typically employed in PFPS rehabilitation programs. In terminal extension, the compressive and mechanical forces that can increase PFPS symptoms are reduced (Wild et al., 1982). This position also significantly reduces the amount of patellofemoral joint reaction forces (DeHaven, Dolan, & Mayer, 1979; Insall, 1979; Kramer, 1986; Malek & Mangine, 1981; Steadman, 1979). Therefore, this type of exercise can be immediately incorporated into a rehabilitation program because it does not result in pain or crepitus in the patellofemoral joint (Kramer, 1979). In addition, the VMO is considered to be the most active in the final degrees of extension (Boucher et al., 1992; Cerny, 1995; Soderberg & Cook, 1983; Soderberg, Minor, Arnold, Henry, Chatterson, Poppe, & Wall, 1987). Gryzlo, Patek, Pink, & Perry (1994) found that VMO and VL activity increase in the last 0-15° of extension, and Wild et al. (1982) found that terminal knee extension was the main component causing maximal activity in the vastus group during all exercise test conditions. Furthermore, in single-joint knee extensors such as the VMO and VL, muscular activity is greatest during isometric contractions (Karst & Jewett, 1993). Consequently, isometric quadriceps contractions in terminal extension are the most appropriate exercises to use in the early stages of rehabilitation for patients with PFPS (Wild et al., 1982).

Several limb positions have also been suggested to further enhance the VMO. Wheatley & Jahnke (1951) found that external rotation of the hip increased VMO activity. The most substantial evidence in support of this finding has come from anatomical and biomechanical studies that have demonstrated a functional link between the VMO and the adductor magnus muscle. The VMO partially originates from the fascia overlying the adductor magnus muscle which assists external rotation of the hip (Antich & Brewster, 1986; Bose et al., 1980). Therefore, simultaneous activation of the adductor magnus and the quadriceps muscle group should facilitate preferential activation of the VMO by providing a more stable proximal attachment (Karst &Jewett, 1993; Reynolds et al, 1983). A second rational suggests that medial joint structures such as the joint capsule and medial collateral ligament are stressed when the hip is externally rotated. This stress provides dynamic support by aiding and protecting the passive structures resulting in VMO activation (Karst & Jewett, 1993). However, more current EMG studies have found evidence that fails to support the use of hip external rotation to increase VMO activity (Cerny, 1995; Karst & Jewett, 1993; Wild et al., 1982). Wild et al. (1982) found that with the knee in terminal extension, rotation of the hip between internal, neutral, and external rotation did not enhance the muscle activity of the vastus group.

Electromyographic (EMG) Biofeedback

Recently, a new paradigm has emerged for the correction or modification of the muscular imbalance between the VMO and the VL. As PFPS is now being considered a motor control problem, EMG biofeedback can play an important therapeutic role for modifying and changing the activity of

the VMO and VL (Karst & Willett, 1995).

EMG biofeedback is a technique used to teach an individual to increase awareness and assist the development of voluntary control over physiological processes normally unconscious and/or under less voluntary control (Olson, 1987; Partin, 1989). This is accomplished by first learning to control the EMG biofeedback signals and then by using internal psychophysiological cues, which is done by providing outcome oriented performance knowledge in response to these processes (Figure 5) (Basmajian & Wolf, 1990; Olson, 1987). Specifically, EMG biofeedback allows for the formulation of strategies for improving motor control or enhancing the efficacy of therapeutic exercise by providing unambiguous, accurate, and relevant information to the patient and the provider (Basmajian & Wolf, 1990; Krebs, 1990; Schwartz, 1987).

EMG Biofeedback Signal / Feedback

The EMG biofeedback signal arises from a muscular contraction. The biofeedback signal then travels through the instrumentation and translates into a visual feedback signal that the participant can interpret into meaningful information (Krebs, 1987; Olson, 1987; Starkey, 1993). This allows for the development of strategies and the ability to test them against the provided feedback (Krebs, 1990). EMG biofeedback signals generate a precise and concurrent source of information which provide the means for the discernment of discreet differences in physiological sensation (Basmajian, 1983; Glaros & Hanson, 1990). Individuals use the instantaneous knowledge of results to learn to manipulate the signals in order to control and change specific involuntary events (Basmajian, 1981; Olson, 1987). Thus allowing

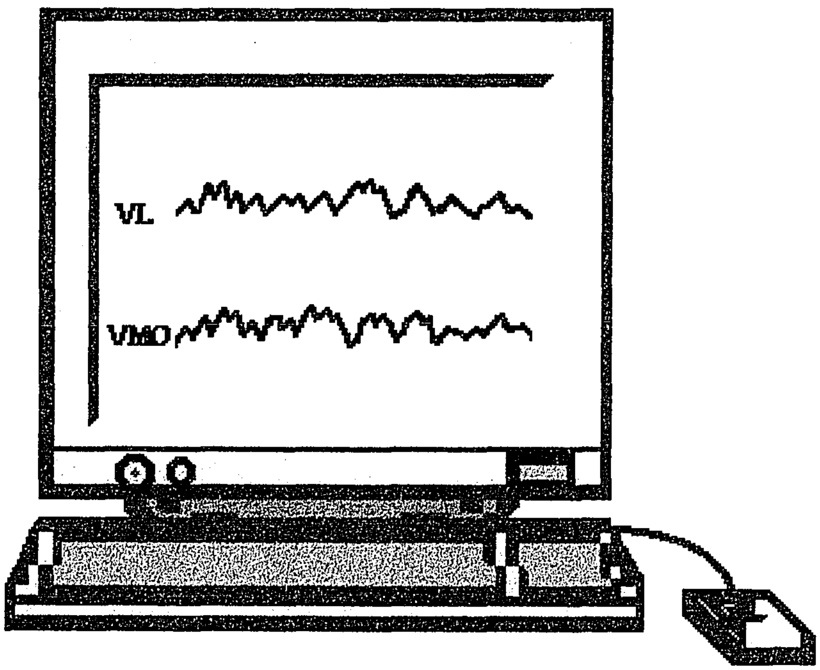

Figure 5: EMG Biofeedback Signal

greater control to be gained through repetition, practice, and increased knowledge of results. Information obtained from the EMG signals supply augmented feedback on motor unit activity to the participant (Hooker, 1990) which acts to enhance awareness of muscular output, or of a cause, or consequence of that function (Glaros & Hanson, 1990).

EMG Biofeedback Instrumentation

EMG biofeedback is dependent upon the conditions related to a response (the electrical activity associated with a muscular contraction) rather than the actual response (the force of the contraction) (Starkey, 1993). Electrical activity or an electrical charge is produced by stimulation of an action potential leading to a contraction. EMG biofeedback units measure and record the action potentials that arise in muscles during rest and voluntary contraction and use this inherent electrical activity to selectively train muscles to increase or decrease tension (Hooker, 1990; Starkey, 1993).

An EMG biofeedback instrument is a sensitive voltmeter capable of measuring overall changes in electrical activity. The electrical activity created by a muscle is sensed by electrodes in a bipolar arrangement and is measured in standard quantitative units called microvolts (Prentice, 1994). The electrodes pick up the electrical energy and transmit it to the EMG biofeedback unit. This signal is filtered to remove the extraneous electrical activity on the skin and to reduce the normal minor fluctuations present in the muscle's electrical output (Krebs, 1987; Prentice, 1994). The EMG electrical energy that remains is amplified and converted into meaningful information. After filtering and amplification the result is an EMG signal that reflects the true electrical activity in the selected muscle. Changes in the

electrical signal produce high frequency fluctuations which are eliminated through a process called rectification which smooths and integrates the signal. Integration measures the resulting signal for a specified period of time forming the basis for quantification of the EMG activity (Prentice, 1994).

EMG Biofeedback for Rehabilitation

Neuromuscular reeducation, according to motor learning models, is the restructuring of action plans or motor programs. These models also include sensory feedback as a crucial ingredient in motor skill acquisition. Feedback is responsible for strengthening corrections, monitoring errors, and ordering changes necessary for the motor program (Colborne & Olney, 1990). EMG biofeedback can provide additional information needed when joint feedback is distorted and incomplete, or feedback for muscle activity that a patient is not normally able to perceive. During muscle contraction and relaxation EMG biofeedback allows the patient to hear or see the result of their efforts. This type of feedback is important for the development of new motor skills (Mulder, Hulstyn, & Van der Meer, 1986) and for gaining strength (Lucca & Recchiuti, 1983).

Draper (1990) found that subjects using EMG biofeedback following ACL reconstruction exhibited superior recovery of function in their quadriceps femoris muscle as compared to subjects not using EMG biofeedback. Draper concluded that EMG biofeedback facilitated the relearning process because the feedback provided by the EMG monitor was instantaneous and qualitative with respect to their efforts to track the quadriceps femoris muscle activity during exercise. LeVeau and Rogers (1980) used EMG biofeedback to train subjects to contract the VMO independent

of the VL. Without specific training it is nearly impossible to contract a quadriceps muscle independently. In disorders such as hypermobile patella or chondromalacia (knee dysfunctions related to PFPS), muscle imbalance can severely hinder recovery. Regular resistance exercises can strengthen both segments of the quadriceps thus maintaining the unwanted imbalance. Glaros and Hanson (1990) also found that for tasks requiring discriminative muscle control EMG biofeedback training can greatly improve performance.

In addition to learning muscle control, regaining strength is an important component in rehabilitation programs. Lucca and Recchiuti's (1983) results support the use of EMG biofeedback to aid in strength gains. Surface electrodes were placed over the rectus femoris muscle belly which became the source of the EMG biofeedback. Two groups performed isometric quadriceps contractions, yet only one of those groups received EMG biofeedback from the surface electrodes on the rectus femoris. One group did not exercise. The group that was provided with EMG biofeedback showed significant gains in strength as compared to the other two groups. It was concluded that EMG biofeedback empowered subjects to increase tension during isometric muscle contractions by increasing awareness of internal cues.

The Role of EMG Biofeedback in Motivation

The influence of feedback has been shown to have positive motivational effects on motor task performance (Salmoni, Schmidt, & Walters, 1984). EMG biofeedback can be considered a motivational modality because it provides information regarding exercise performance. Enhanced awareness of individual performance levels can act as an inspiration to push

toward performance goals. Effort and desired outcome can increase when presented with quantitative goals and a way to monitor effort. EMG biofeedback can provide such motivational information by generating feedback signals that represent otherwise masked muscle activity. Draper (1990) found that patients who were trained with EMG biofeedback showed more awareness and control of their muscle contractions during exercise than did the group that did not use EMG biofeedback. It was also found that the patients that employed EMG biofeedback demonstrated an increased capability to set and achieve exercise goals. During muscle contraction, EMG instrumentation monitors and provides feedback as to the magnitude of motor unit recruitment. This acts as a means of confirming and reinforcing the fact that the desired motor response was made thus promoting future correct responses (Draper, 1990).

CHAPTER 3

METHODS

Participants

Thirty-six female volunteers who had no known right knee musculoskeletal dysfunction served as participants for this study. Their average age, height, and weight were 20.1 ± 1.2 years, 166 ± 8.0 cm, and 59 ± 11.5 kg respectively. This study was approved by Human Subjects Committee. All participants read a description of the study, signed an informed consent form, filled out a short questionnaire and were randomly assigned to one of three experimental groups.

Equipment

EMG Biofeedback was provided by the Norodyn 2000 EMG biofeedback unit. The unit provided continuous visual feedback. Three sets of Norotrode 2.0 silver/silver chloride surface bipolar electrodes were used. These disposable electrodes consist of a 2-inch strip of tape with two pre-jelled cup electrodes. Interelectrode spacing was 20.0 ± 1mm. The offset potential was 1.0 mv, and the impedance of the electrodes at 60 Hz was approximately 20 ohms.

One set of electrodes was placed over the greatest bulk of the VMO muscle and a second set was placed over the greatest bulk of the VL muscle. A third set of electrodes was placed near the two active electrode sites to

function as the ground. Each site of electrode attachment was marked in ink to ensure consistency in electrode placement for each treatment session. Electrode sites were shaven, abraded, and rubbed with alcohol to reduce resistance to electrical current. Electrical resistance was measured with a voltmeter and required to be under 20,000 ohms.

The Norodyn 2000 computer based EMG unit was set up with two channels, an EMG gain of 50 uV, and a medium integration period. The unit only recorded muscle activity from the VMO and the VL. The sweep speed was one second per division, with 15 divisions across the screen. Processed EMG feedback signals were provided for every contraction and average EMG values for each division were displayed.

Procedures

The protocol for this study spanned five consecutive days: the pretest on day 1, training sessions on days 2 through 4, and the post test on day 5. On the first day consent was obtained, the participant was introduced to the EMG biofeedback machine, the pretest was conducted, and a portion of a full training session was completed (3 sets of 5 contractions). For the pretest, the participant was seated in a comfortable semi-recumbent position with the knee in terminal extension. All testing procedures and training sessions were executed on the right leg only. Participants were instructed to exert only about 50% effort to reduce fatigue. Six 5-second isometric contractions of the knee extensor muscles were performed with a 25-second rest period between each contraction. Two isometric contractions were performed in each of the three target hip positions (maximal internal rotation, maximal external rotation, or the anatomically neutral position). The electrical activity of each

set of two contractions was averaged for each subject. These averages were then used to compute the VMO:VL ratio for each hip position. These procedures for the pretest were duplicated on day 5 as a post test to reassess the electrical activity produced by the VMO and VL.

For each training session, the participants were placed in a semi-recumbant position with the knee in terminal extension and the hip in one of the three target positions according to their random assignment. Assignments were made to either Group A (anatomically neutral position), Group B (maximum hip external rotation), or Group C (maximum hip internal rotation). It was also important to make sure that the participant could easily view the biofeedback monitor as all groups received EMG biofeedback during each training session. Participants were then instructed to perform submaximal isometric contractions of the right quadriceps muscle (approximately 50% of maximal contraction) and to observe the electrical activity displayed on the computer screen. Each isometric contraction was 10 seconds in duration with a 15 second rest period between each contraction. Five contractions and four rest periods constituted each set, and five sets constituted a training session. All participants were informed that the EMG biofeedback unit monitors electrical activity of the thigh muscles, and that the amplitude of the lines drawn by the EMG biofeedback unit represent the amount of effort used during contraction of the thigh muscles (Figure 5). Participant were told to concentrate and attempt to increase the amplitude of the line associated with the VMO and to lower the line that corresponds to the VL. No form of encouragement or suggestion of strategy was provided to the participants.

Data Analysis

A 3 x 2 factorial repeated measures analysis of variance (ANOVA) with repeated measures on the last factor was used to analyze the data. The electrical activity of each contraction during the pretest and post test was recorded for each participant. Data analyses were conducted on the contractions performed in the hip position used by the participant in training. Thus, only two sets of contractions were used for each test. Mean VMO values were divided by the mean VL values to obtain the VMO:VL ratio. This was completed for both the pretest and the post test, and represented the data used in the final analysis. An effect size test was used to determine the meaningfulness of the findings by estimating the magnitude of the differences between the groups (Thomas, Salazar, & Landers; 1991).

CHAPTER 4

RESULTS

The VMO:VL ratio of myoelectric activity while performing isometric quadriceps contractions for 5 seconds during the pretest and post test is presented in Table 1. The mean ratio of electrical activity during the initial session was 1.028 for Group A, 0.893 for Group B, and 0.773 for Group C. These mean ratios changed when the electrical activity was measured during the final session. The final ratios were 1.423, 1.485, and 1.036 for Group A, Group B, and Group C respectively. These results are depicted graphically in Figure 1.

The main effect for Group was not significant $\underline{F}$ (2,33) = 2.19, $\underline{p}$ = 0.1278. This finding suggests that the position of the hip does not appear to significantly increase VMO:VL ratios. The main effect for Tests was significant $\underline{F}$ (1,33) = 38.74, $\underline{p}$ = 0.0001. This shows that there was a significant increase in the VMO:VL ratio between the pretest and the post test. The Group x Test interaction was not significant $\underline{F}$ (2,33) = 2.03, $\underline{p}$ = 0.1471 demonstrating no interaction between group and trials. However, the effects size test revealed a meaningful difference between Group A and Group C (.99), and between Group B and Group C (1.1).

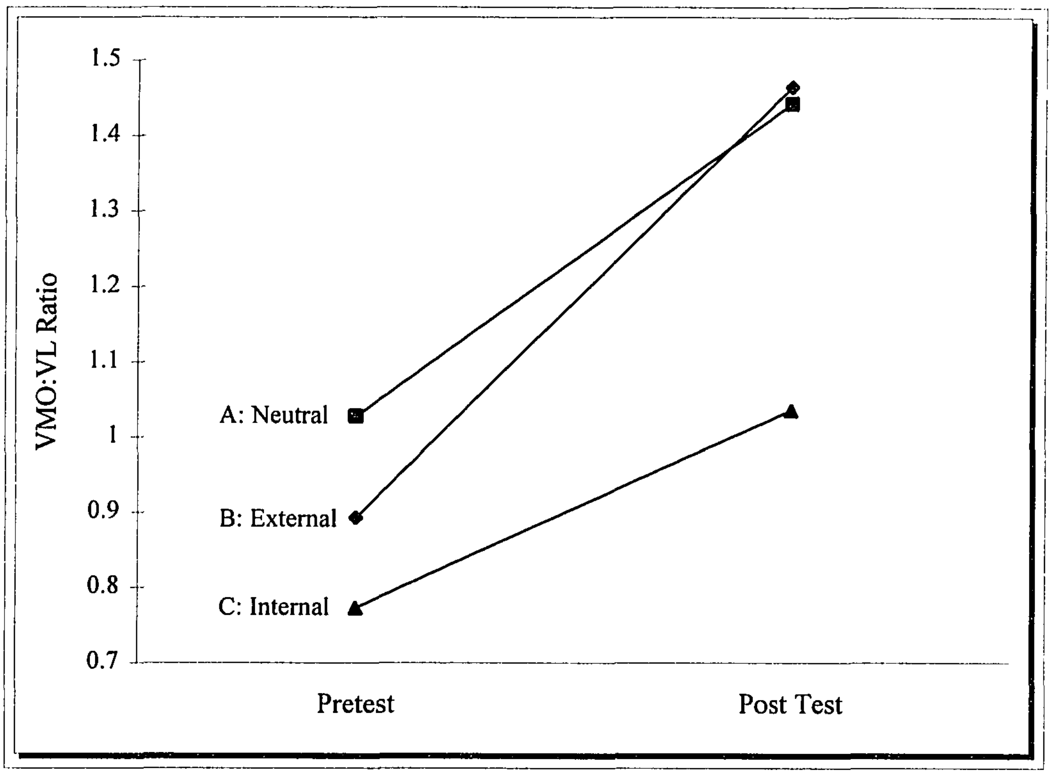

Figure 6: VMO:VL Ratios x Trials

CHAPTER 5

DISCUSSION

The purpose of this study was to determine if the position of the hip had an effect on increasing the VMO:VL ratio using EMG biofeedback. A second purpose was to determine if VMO:VL ratios would significantly increase using EMG biofeedback within a five day period. The results indicated that all participants were able to increase their VMO:VL ratio in 5 days regardless of hip position. The lack of significant differences between groups may be attributed to too much unexplained variability due to the small sample size. Calculation of the effect size (ES) was used to determine the magnitude of the differences among the three groups. A meaningful difference was found between the group trained in external hip rotation and the group that trained in internal hip rotation (ES=1.1). In addition, a meaningful difference was found between participants training in the anatomically neutral position and the participants training in internal hip rotation (ES=.99). An effect size of 0.2 is considered small, 0.5 = moderate, and 0.8 = large (Thomas et al., 1991). The large ES values indicate that hip position does affect the ability to increase VMO:VL ratios when using EMG biofeedback training.

Therefore, the results of this investigation support the use of external

hip rotation to selectively enhance the VMO in relation to the VL. It can also be suggested that internal hip rotation be avoided as a means of increasing the VMO:VL ratio. These results further support Wheatley and Jahnke (1951) who found that VMO activity increased in external hip rotation.

EMG Biofeedback has been shown to be an effective means to selectively train the VMO in relation to the VL (LeVeau & Rogers, 1980; Wild et al., 1982). This study proposed to teach participants to increase their VMO:VL ratio in a five day period. The results of this study suggest that VMO:VL ratios can be increased by using EMG biofeedback during isometric contractions with the knee in terminal extension. Primarily, EMG biofeedback studies involving the VMO and VL have used more training sessions. The results of the present study show a significant difference between the pretest and the post test for each group after only four training sessions. This supports previous studies that demonstrated the ability of participants to learn a novel skill using EMG biofeedback in 5 days (Colborne & Olney, 1990; Koga, 1989; Sabourin & Rioux, 1979).

The findings of this study can be applied to the rehabilitation programs of those patients suffering from PFPS. These results suggest that combining traditional therapeutic exercises with external rotation of the hip should facilitate improved VMO:VL ratios thus increasing the effectiveness of the rehabilitation program. These results further support the claim that EMG biofeedback is an effective modality for selectively training the VMO for the use of PFPS rehabilitation (Ingersoll & Knight, 1991; Wise et al., 1984; LeVeau & Rogers, 1980; Lucca & Recchiuti, 1982). This is important evidence for the PFPS patient seeking a conservative, non-surgical treatment program.

Future Directions

The results of this study support preferential use of external hip rotation in the early stages of rehabilitation of PFPS. However, further research is needed to determine if hip position would have an effect on later stages of EMG biofeedback PFPS rehabilitation programs. This study used apparently healthy participants. Further investigation is needed to determine if the same results would be present when using PFPS patients. Future studies focusing on selective activation of the VMO and PFPS rehabilitation could address both the clinical relevance and reliability of these results by using a larger number of participants.

CHAPTER 6

CONCLUSION

The data presented in this study provides strong evidence for the use of EMG biofeedback as a means of increasing the VMO:VL ratio. The results also showed external hip rotation to be an effective limb position for increasing VMO activity in relation to VL activity. Therefore, therapeutic exercise that incorporates preferential activation of the VMO through external rotation of the hip should facilitate improved VMO:VL ratios thus providing an increased rate of recovery of the balance between the two muscles. Once the balance is restored the symptoms of PFPS should subside.

APPENDIX A

INFORMED CONSENT FORM

CONSENT FOR RESEARCH PARTICIPATION
UNIVERSITY OF NEVADA-LAS VEGAS

TITLE OF STUDY
The Effect of Hip Position and EMG Biofeedback Training on Selectively increasing the Vastus Medialis Oblique in Relation to the Vastus Lateralis.

PURPOSE
You are being asked to participate in a research study. The purpose of this study is to determine if external rotation of the hip is a more effective and efficient position for the purpose of increasing the VMO:VL ratio when compared to training in maximum hip internal rotation or an anatomically neutral position.

SUBJECTS
Subjects for this study will consist of female volunteers from UNLV who do not have a history of injury to their right leg. Females will be chosen for this study to negate treatment effect attributed to gender.

PROCEDURES
If you decide to participate in this study, the following will be required of you:

1. You will need to commit to five laboratory visits, which will last approximately 20 minutes. You will need to wear a athletic shorts and shoes. The sessions will be scheduled at a mutually agreed upon time.
2. The laboratory session will start with instructions as to what is expected of you.
3. You will then be seated in front of the EMG biofeedback unit. Three sets of silver-chloride surface electrodes will be affixed to your right thigh.
4. Training will occur on four consecutive days. You will be asked to perform isometric contractions of your right quadriceps.
5. Subjects will be constantly encouraged to increase VMO activity and to keep VL activity the same.
6. On the fifth day, a post test will be administered that requires only six contractions of the right quadriceps.

RISKS
1. Some localized muscle fatigue and soreness may be experienced toward the end of the treatment sessions.
2. Delayed localized muscle soreness may be experience in the following few days.

BENEFITS

1. The subjects in this study should benefit from exposure to the methods used in the lab.

CONFIDENTIALITY

Your participation in, and the results from the study will remain confidential. No parties or individuals other than those directly involved in the collection and analysis of the data will have access to your file. If the data is presented at a scientific conference or reported in a scientific journal, you will be referred to by a subject identification number and not by your name. After completion of the experiment the informed consent and all other data will be kept in a locked cabinet within the principle investigator's office.

RIGHT TO REFUSE OR WITHDRAW

Participation is voluntary and you may withdraw from participation at any time. However, in the event of extreme difficulties in scheduling or failing to appear for a scheduled appointment without notifying the tester may result in your termination from the study.

QUESTIONS

If you have any questions regarding the study, please ask. I can be contacted at the following number: Tina Davlin at 895-4494.

Or you can contact the Office of Sponsored Programs at 895-1357 (for questions about the right of research subjects).

For rescheduling or cancellation

Call the Sports Injury Research Center at: 895-4494

You will be given a signed and dated copy of this form to keep

****

MY SIGNATURE BELOW INDICATES THAT I HAVE DECIDED TO VOLUNTEER AS A RESEARCH SUBJECT AND THAT I HAVE READ THE INFORMATION PROVIDED ABOVE.

______ ______________________________

Date Name of participant (print) Signature

______ ______________________________

Date Name of witness (print) Signature

APPENDIX B

SAMPLE QUESTIONNAIRE

Questionnaire

Name ______________________________

Age ________________________________

Height ______________________________

Weight ______________________________

Check if you have experienced any of the following:

_____ Fracture to any of the bones in the right leg.

_____ Significant soft tissue injury to the right leg. (sprains &/or strains)

_____ Suffered an injury to the right leg that required you to see a Doctor.

APPENDIX C

HUMAN SUBJECTS APPROVAL

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

DATE: January 19, 1996

TO: Christina Davlin (KIN)
M/S 3032

FROM: Dr. William E. Schulze, Director
Office of Sponsored Programs (X1357)

RE: Status of Human Subject Protocol Entitled:
"The Effects of Hip Position and EMG Biofeedback on the Selective Enhancement of the Vastus Medialis Oblique"

OSP #351s0196-123e

The protocol for the project referenced above has been reviewed by the Office of Sponsored Programs, and it has been determined that it meets the criteria for exemption from full review by the UNLV human subjects Institutional Review Board. Except for any required conditions or modifications noted below, this protocol is approved for a period of one year from the date of this notification, and work on the project may proceed.

Should the use of human subjects described in this protocol continue beyond a year from the date of this notification, it will be necessary to request an extension.

cc: W. Holcomb (HESIM-3032)
OSP File

Office of Sponsored Programs
4505 Maryland Parkway • Box 451037 • Las Vegas, Nevada 89154-1037
(702) 895-1357 • FAX (702) 895-4242

APPENDIX D

SUBJECT DATA SETS

TABLE 1

Initial and final EMG VMO Ratios

GROUP A (hip in neutral position)

Subj	PRETEST	POST TEST	DIFFERENCE
1	0.67	1.96	+1.29
2	1.41	1.94	+0.53
3	1.31	1.41	+0.10
4	0.88	1.06	+0.18
5	1.10	1.32	+0.22
6	0.66	1.34	+0.68
7	0.96	1.43	+0.47
8	0.56	0.91	+0.35
9	1.10	1.69	+0.59
10	1.83	1.85	+0.02
11	0.90	0.96	+0.06
12	0.96	1.21	+0.25
x	1.028	1.423	+0.395

GROUP B (external hip rotation)

Subj	PRETEST	POST TEST	DIFFERENCE
13	0.56	0.94	+0.38
14	1.04	1.19	+0.15
15	0.68	2.83	+2.15
16	0.66	0.97	+0.31
17	0.60	1.90	+1.30
18	0.53	1.94	+1.41
19	0.69	0.87	+0.18
20	0.60	1.12	+0.52
21	2.29	2.39	+0.10
22	0.43	0.85	+0.42
23	0.91	1.45	+0.54
24	1.12	1.37	+0.25
x	0.893	1.485	+0.643

GROUP C (internal hip rotation)

Subj	PRETEST	POST TEST	DIFFERENCE
25	1.39	1.70	+0.31
26	0.37	0.56	+0.19
27	0.27	0.74	+0.47
28	0.76	0.99	+0.23
29	0.92	1.33	+0.41
30	0.41	0.73	+0.32
31	0.97	1.11	+0.14
32	0.57	0.88	+0.31
33	1.12	1.36	+0.24
34	1.03	1.21	+0.18
35	0.96	1.10	+0.14
36	0.50	0.73	+0.23
x	0.773	1.036	+0.264

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