Comparison of EMG Activity of Knee Extensor Muscles in Knee Extension and Leg Press

Damirchi, A[1]., Jalali, M[2]., Rahmaninia, F[3]., Mohebbi, H[3]

[1]Assistant Professor, Physical Education & Sport Sciences, Guilan University
[2]Master, Physical Education & Sport Sciences, Esfehan University
[3]Associate Professor, Physical Education & Sport Sciences, Guilan University

Abstract

The purpose of this study was to compare the EMG activity of Vastus Medialis Oblique (VMO) and Vastus Lateralis (VL) muscles in the single- joint knee extension (KE) and the multi- joint leg press (LP). Subjects performed two maximal voluntary isometric contractions (MVC) and LP and KE actions subsequently performed at individual load, equal 80% of MVC in each exercise modality. 15 healthy men, (mean age 31.93 ± 7.08 yrs, mean height 176.6 ± 5.93 cm, mean weight 72± 12.62 kg) with no previous of knee pain, trauma, surgery, or other joint disease participated in the study.The EMG signal of VMO and VL muscles was recorded bilaterally during both exercises. Results showed no significant difference between LP and KE. However when EMG activity of VMO and VL muscles were compared whit each other, a significant difference was found ($p \leq 0.05$), and in both action the activity of VMO was more than VL. Regardless of the exercise model this suggests the increased demand of involvement may not be equally shared among muscles possessing different anatomical origin and insertion. Motor control plays an important role in rehabilitation in general and patellofemoral joint problems in particular.

Key Words: Average Electromyography (AEMG), Vastus Medialis Oblique (VMO), Vastus Lateralis (VL)

Introduction

Studies of neuromuscular system often employ recordings of the electrical of skeletal muscle. These electromyographic recording may be of electrical signals detected within a muscle via needle or wire electrodes or from the surface of the skin via surface electrodes. Surface electromyography (SEMG) is frequently used to estimate the amount of muscle activation required for specific tasks (Soderberg and Cook, 1983; Veiersted et al; 1990) and to examine changes in muscle activation as a result of training (Narici et al, 1989) [1].

Weakness is the most prominent impairment in neuromuscular disorders. The usefulness of strength training is, however, still being debated [2]. Patellofemoral pain (PFP) is a common condition characterized by diffuse anterior knee pain particularly when climbing stairs, kneeling, or sitting whit the knees flexed for a long period of time [3].

Muscular strength, tightness and neuromotor control all play significant roles in patella pain syndromes and especially in the rehabilitation of those syndromes [4]. PFP may be caused by a faulty extensor mechanism in which the patella does move smoothly through the femoral groove when the knee is flexed and extended [3, 5]. Patellar position in maintained by the balance of static and dynamic forces that act upon the patella [6]. The quadriceps femoris exerts the most direct effect on the relationship of patella to the trochlear groove [4]. For normal tracking to occur the lateral and medial forces acting upon the patella must be balanced [3]. An altered motor control pattern between the vastus medialis oblique (VMO) and vastus lateralis(VL) has been reported as a common dynamic dysfunction that disrupts this force balance[3]. It is thought that the VMO may be weak relative to the VL, or delayed firing of the VMO cannot counteract the lateral force vector produced by the VL and iliotibial band. Therefore, the patella may be pulled laterally [3,7].

Research literature overwhelmingly supports the use of exercise in managing patellofemoral pain syndromes [8-10]. Various attempts have been made to distinguish exercises that promote VM and VMO muscle activity as compared to the other quadriceps femoris muscles, often using EMG. Frequently, clinicians prescribe terminal knee extension exercise (static quadriceps, straight leg raises, and short- arc quads) to promote vastus medialis strength and avoid pain [10,11]. While these exercises may be effective in limiting pain, EMG studies do not substantiate increased VM muscle activity in terminal knee joint extension [12, 13]. Some reports suggest that EMG activity of individual muscles in not uniform in multi- joint leg press (LP) compared whit single-joint knee extension (KE) exercises [14,15]. Thus, EMG activity of extensor Muscle might be different in LP and KE actions [16]. To our knowledge, no study has compared the EMG activity for VMO and VL muscles during both LP and KE exercise. Libe and Perry describe active VM muscle participation throughout the range of knee extension and consistent participation of the entire quadriceps femoris muscle [13, 17]. Clinically, this fails to create the increased medial pull of the patella that is desired by most exercise programs [14]. Thus, the purpose of this study was to compare the EMG activity of VMO and VL muscles in the single- joint knee extension and the multi- joint leg press. The null hypothesis was that there would be no difference in the EMG activity of the VMO and VL during LP and KE action.

Methods

15 healthy men, (mean age 31.93 ± 7.08 yrs, mean height 176.6 ± 5.93 cm, mean weight 72 ± 12.62 kg) participated in the study. Subjects were excluded if they had a current or previous record of knee pain, trauma, surgery, or other joint disease or were involved in competitive sports [18, 19]. All subjects gave informed consent as approved by university insituational review board before participating in the study. The board also approved the study [20].

EMG activity was recorded and stored using a ME3000P_8 muscle tester (mega Electronics Ltd, P.O.BOX1750, FIN_ 70211 Kuopio Finland). EMG data were analyzed using the ME3000PV1.2 computer software (Mega Electronics Ltd, Finland).

After the skin was prepared and the electrodes attached, the subjects performed a 5 min warm- up on a stationary bicycle at an easy, self- selected pace [3]. First, subjects performed two maximal voluntary isometric contractions (MVC), and if force differed more than 5% between trials a third trial was allowed. To minimize potential influence of fatigue, KE and LP actions were performed in a random order on the same day. Two actions subsequently performed at individual load equal 80% of MVC in each exercise modality. Subjects were required to increase force smoothly to the predetermined level, and once established that set force was sustained for 2-3s. Visual feedback was provided such that the required force was displayed on a screen. If the subject failed to maintain the set level within a ± 5% margin off- set, a new trial was allowed [16]. One-minute rest was allowed between each action. Seated knee extension and flexion were performed in a dynamometer described elsewhere [21] by applying force onto the lever arm pad attached to lower leg. The leg press was performed in an ergometer designed for the seated leg press [22] by applying force onto a footplate. Fixation was ensured by strapping back (LP, KE), shoulders, and thigh (KE). In either modality, subjects held their arms crossed over their chest. Knee angle, measured using an electrogoniometer aligned whit the rotation axis of the knee joint, was 90º (180º= fully extended) and hip angle was about 115º (180º= fully extended). The foot was always kept in neutral position [16].

The skin was shaved and vigorously scrubbed white alcohol to reduce skin impedance prior to the attachment of the electrodes [3,4,23]. Bipolar silver- silver chloride surface electrodes (diameter 2 cm, skintact, Austria) were positioned over the most prominent part of the muscles (VMO: 10 cm above and medially from the superior border of the patella and VL: half way between the lateral femoral epicondyle and greater trochanter). The distance between the centers of recording electrodes was 4 cm. The two ground electrodes were positioned on the quadriceps tendon and the lateral femoral epicondyle, respectively [24]. The electrodes were secured whit adhesive tape and the wires were secured around the subjects, waist whit a Velcro strap [3].

The EMG signal was recorded by amplifiers positioned to the ground electrodes whit a gain of 360, a common mode rejection ratio greater than 130 db and a frequency pass- band of 20- 500 HZ. The input noise level was less than 1 µv in the measuring band. The signal was collected at 1000 HZ, converted to digital from using a 16-bit analogue to digital convector and stored in a portable microcomputer [24]. Raw EMG data of Average EMG (AEMG) were collected and stored on a Pentium IV 2800 MHZ desktop PC whit the use of custom software Megawin V.2.01 [19,24]. The AEMG signal is rectified by smoothing the signal over a period of 10 ms [3,24]. Paired t- test were analyzed between the two exercises on EMG activity of VMO and VL muscles [4]. The α level for all statistical tests was set at $P \leq 0.05$.

Results

Results showed no significant difference between LP and KE (table 1). However when EMG activity of VMO and VL muscles were compared whit each other, a significant difference was found ($p \leq 0.05$) and in both action the activity of VMO was more than VL (table 2).

Table 1: Paired t- test for LP and KE actions on AEMG of VMO and VL

Variable	Mean	standard devitation	Mean	Standard deviation	differen ce
AEMG- VMO- LP	5883.8 µV	1238.8	322	251.1	1.228
AEMG- VMO- KE	5561.8 µV	1489.9			
AEMG- VL- LP	3821.4 µV	382.2	96.5	447.5	0.646
AEMG- VL- KE	3724.9 µV	829.7			

(*P ≤ 0.05)

Table 2: Paired t- test for AEMG of VMO and VL in LP and KE

Variable	**Mean**	**standard devitation**	**Mean**	**Standard deviation**	**t**
AEMG- VMO- LP	5883.8 µV	1238.8	2062.4	856.6	7.401*
AEMG- VL- LP	3821.4 µV	382.2			
AEMG- VMO-KE	5561.8 µV	1489.9	1836.9	660.2	5.906*
AEMG- VL- KE	3724.9 µV	829.7			

(*P ≤ 0.05)

Discussion

Our results concur whit previous research that has reported [3,4,16]. Alkaner et al. reported the EMG/ Force relationship is similar for the single- joint knee extension and the multi- joint leg press exercise for either quadriceps femoris (QF) or individual QF muscles. There were, however, differences in the EMG/ Force relationship among individual muscles, such that it was nonlinear for VM and RF, yet linear for VL [16]. The QF muscles group is the sole contributor to generate force in the KE, in the LP exercise additional muscle, including hip and ankle extensors, are brought into action and this might affect the QF EMG/ Force relationship [14,16].

Rici et al. investigated the effects of combining isometric hip adduction and open chain knee extensions. Although they found no selective VMO recruitment they did see a decrease in even VL activity when adduction was added. They hypothesized that if the VMO is not affected, decreasing VL activity during an open chain exercise can be helpful in correcting the extensor mechanism [4]. Several studies have attempted to selectively recruit VMO fibers whit variable success [12, 25]. Terminal knee extensions are typically prescribed for PFP rehabilitation, but these have not been reported to increase VMO activity [4]. One method hypothesized to increase VMO fiber recruitment is the addition of hip adduction exercises to quadriceps strengthening programs. The rationale is that some of the fibers of the VMO originate off the distal portion of the adductor magnus, therefore activating this muscle may affect the VMO [4,21]. Independent of knee motion, when isometric hip adduction exercises are done in an open chain manner there has been reports of increases in VMO and VL activity [12]. There is debate about whether this is caused by neural connection between the VMO and adductor magnus, or as result of valgus force at the knee [10, 12]. Sczepanski et al found significantly increased VMO: VL ratio in healthy subjects at angles ranging from 60º to 85º of knee flexion compared whit the ratio for 10- 35º of knee flexion. It was also reported that the EMG activity of VM was greater during eccentric compared with concentric muscle action. The present findings did not identify any significant differences in the activation patterns of the individual knee extensor muscles throughout the ROM [5[. This is in agreement with other study on isokinetic concentric knee extension [12] and closed kinetic chain leg extension [24]. Draganich, Jaeger and Kralj identified differences in the activation of the knee extensor muscles during knee extension without resistance. However when the load of the movement increased, these differences were not evident [26].Ingersoll and Knight used EMG biofeedback training for 3 weeks, to selectively enhance recruitment of the VMO. Results showed that selective activation of the VMO through biofeedback prevented lateral subluxation by medially relocating the patella [27,28].

The entire quadriceps mechanism is responsible for patella tracking. Equally increasing each component of the quadriceps will increase the magnitude of the vector, but not affect its direction, and patellar balance remains unchanged [29]. To reduce this lateral pull, the VMO must be selectively activation and/ or the VL less activated [4]. Finally, this study was performed on normal subjects in one day. Mariani and Caruso, and Souza and Gross, have reported decreased vastus medialis muscle EMG values in patients whit patellofemoral pain compared to healthy subjects, suggesting that abnormal activation patterns may interact whit biomechanical factors in explaining the cause of patellofemorall joint syndrome [29,30]. Since subjects in this study had no patellofemoral joint symptoms or sings, they may have normal activation patterns whit minimal opportunity for improvement or alteration in VMO recruitment or increased activity [4]. The present study reports that EMG activity among the VMO and VL muscles does vary throughout the range of motion in the single- joint knee extension and multi- joint leg press. The reproducibility or surface EMG measurements across trials was quite similar for the two exercise modalities and the two muscles studied and of similar reasonable magnitude to what has been reported elsewhere [4]. Yet there are certainly inherent methodological problems associated with use of the surface EMG technique. e.g., cross talk between adjacent muscles, inaccessibility to certain muscles or portions of muscles, or lack of linearity in signal output from the recorded pick- up area[16]. These limitation should no be neglected when interpreting the results of this study. We believe, however, that the study design employed allowed us to assess and compare the EMG activity of individual knee extensor muscles in the knee extension and the leg press, where the result suggest muscle use to be very similar. The comparison between EMG activity of the VMO and VL muscles shows a striking similarity in multi- joint leg press and single- joint knee extension actions. It seems, however that there are differences in EMG activity the VMO and VL.

Summary and Conclusions

Regardless of the exercise model this suggests the increased demand of involvement may not be equally shared among muscles possessing different anatomical origin and insertion [16]. Motor control plays an important role in rehabilitation in general and patellofemoral joint problems in particular [4,31]. McConnell, Bennett and Stauber, and Sale and Knight, have all demonstrated the body's ability to adapt rapidly and via motor learning to enhance both strength and function [4]. Biofeedback, including visualization, verbal command, electromyography and exercise has all been effective in muscular reeducation, as well as in the more common application for strength gains. It may be beneficial to repeat this study by pre-testing subjects first, followed by several weeks of training and then post- testing to see if increased VMO activity occurs as a result of neural adaptation to training [3, 4]. Many of these studies have been inconclusive in terms of identifying differences between PFP patients and healthy persons, and in term of which exercises best rehabilitate the presumed dysfunction. Perhaps this is an indication that the distal quadriceps alone is not the source of the dysfunction. Future research should attempts to examine other factors that have a direct influence on quadriceps activity, while continuing to investigate VMO, VL relationship [3].

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