The effects of patellar bracing on quadriceps EMG activity during isokinetic exercise

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Abstract

Patellofemoral pain syndrome is a prevalent ailment experienced by a number of individuals participating in regular physical activity. Little information is available concerning the effects of patellofemoral bracing on the function of the extensor mechanism in patellofemoral malalignment patients. The purpose of this study was to examine the effects of patellar bracing on the extensor mechanism in relation to isokinetic exercise. Sixteen subjects exhibiting patellofemoral pain symptoms were tested on an isokinetic dynamometer with and without a patellofemoral brace. The testing procedure involved three maximal concentric/eccentric quadriceps contractions at an angular velocity of 180°/s. Electromyographic (EMG) activity of the vastus medialis obliqus (VMO) and the vastus lateralis (VL) were recorded during testing. Integrated EMG activity (IEMG) was analyzed by a three-way ANOVA with repeated measures ($P < 0.05$). The results indicated that the application of the patellar brace resulted in a significantly smaller IEMG signal than during the non-braced condition in both the VMO and VL during both concentric and eccentric contractions ($P < 0.05$). The IEMG signal of the VMO was found to be significantly greater than the VL regardless of test or brace condition ($P < 0.05$). Moreover, the IEMG signal was also found to be significantly greater during the concentric contractions than the eccentric contractions during all testing conditions ($P < 0.05$). The clinical implication from this study suggests that muscle activation of the VMO and VL were reduced with the use of the brace. This type of bracing may provide mechanical support to the patellofemoral joint as evidenced by the reduction in quadriceps activation during isokinetic knee extension exercise. Copyright © 1996 Elsevier Science Ireland Ltd.

Keywords: Patella; Brace; Electromyography; Isokinetic

1. Introduction

Anterior knee pain is one of the most common knee problems experienced by recreational and elite athletes. Although there is no formal clinical definition of patellofemoral pain syndrome, PFPS, it is often characterized by a diffuse, poorly localized pain that arises from abnormal tracking of the patella [7]. It is currently believed that an underlying etiology of PFPS is malalignment of the patellofemoral joint, resulting from pathological conditions producing anterior knee pain [17]. Patellar malalignment is well recognized as a potential cause of chondromalacia and, more specifically, as a cause of patellofemoral pain. Malalignment, in its simplest sense, may be considered abnormal tracking of the patella in the trochlear groove during functional activities. Patellofemoral malalignment may be a result of an imbalance of the extensor mechanism [2,3,12–14,16–18], specifically the vastus medialis oblique (VMO) and the vastus lateralis (VL), abnormal anatomical architecture [3,12,16–18], increased Q-angle [2,12,15,16], genu valgus, genu recurvatum, pronated feet, femoral neck anteversion, hypermobile patella [14–16], patella alta [11,14–16], abnormalities in the patellar retinacular restraints [3,17,18], ilio-tibial band syndrome and VMO insufficiency [2,12,14–16]. Correct biomechanical alignment of the extensor mechanism has therefore been suggested to be partly

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dependent upon a properly functioning VMO [16].

Conservative treatment of patellofemoral pain syndrome is perhaps the most commonly used approach for dealing with this ailment, as opposed to surgical intervention. Such treatment options have included hamstring flexibility exercises, quadriceps strengthening (specifically the VMO), aquatic exercises, salicylates, non-steroidal anti-inflammatory medications, analgesics, arch orthosis, immobilization of the patella and patellar bracing [1,10].

The quadriceps extensor mechanism has been studied from several viewpoints, usually torque, muscle force and biomechanics, electromyography (EMG) and radiography. With respect to biomechanics, the patella functions in a variety of roles. The patella's primary function is to increase the extensor mechanism's moment arm and therefore increases its efficiency and mechanical advantage during knee extension [6]. Secondly, it functions to decrease the friction and shearing of the patellar tendon, allowing it to withstand high repetitive loads. Likewise, the patella functions to centralize the divergent heads of the extensor mechanism by neutralizing the four different vectors of the quadriceps muscles [5] (Fig. 1).

The ability to alter function of the extensor mechanism by the use of patellar bracing has been suggested to alleviate symptoms of patellofemoral pain syndrome [15]. Advocated functions of patella braces include improvement of tracking, dispersal of force, maintenance of patellar alignment, prevention of straining the medial retinaculum and prevention of subluxation and dislocation [2,11,13,15]. Although, Cherf [2] suggested that bracing has often been used in conservative treatment of patellar instability, its physiological function has not received much investigation. The purpose of this study was to examine the effects of patellar bracing on EMG activity of the vastus lateralis and vastus medialis muscles during isokinetic knee exercise.

2. Materials and methods

Sixteen athletically active individuals with a mean age of 24.5 years (range, 18–38 years) volunteered to participate in this study. All the subjects entered into this study were concurrently participating in physical therapy in an out-patient clinical setting. After subjects provided written informed consent approved by the Biomedical Institutional Review Board at the University of Pittsburgh, demographic data including past history of knee pathology, knee surgery and symptoms of patellofemoral pain was obtained. Criteria for inclusion in this study were point tenderness upon palpation of the medial patellar facets, no history of knee surgery or traumatic knee ligamentous injury, no isokinetic training experience, demonstrated symptoms indicative of patellofemoral pain syndrome and one or more abnormal values reported from a Merchant-view roentgenogram. Subjects were evaluated by one orthopedic physician to screen for patellar facet tenderness. All subjects demonstrated full knee range of motion (approximately 135–140°), no pain during a maximal manual quadriceps strength test and reported no previous lower extremity strength training 3–4 months prior to testing. All subjects were also full weight bearing and reported minimal pain during light daily activities. Each subject was evaluated for isokinetic strength with the application of the patellar knee brace and without brace application. The order of the two testing procedures were randomly assigned.

2.1. Instrumentation

Subjects were tested on the Kinetic Communicator II (Kin-Com) isokinetic dynamometer (Chattex Corp, Chattanooga, TN). The patella orthosis chosen for patellar bracing was the U1004-patellar stabilizer (Sports Supports Inc., Irving, TX) which consists of a neoprene sleeve with a cut out for the patella and a felt horseshoe buttress that surrounds the patella along its superior border. Cleartrace LT disposable adhesive gel silver/silver-chloride surface electrodes (Medtronic Andover Medical, Haverhill, Massachusetts) were used to record myoelectrical activity of the VMO and VL.

2.2. Isokinetic assessment

Each subject was positioned in an upright, comfortable seated position on the Kin-Com Dynamometer chair. The back support was adjusted, allowing the subject's thigh to be supported as well as allowing the knee to be tested to move beyond 90° of knee flexion. The anatomical axis of the knee being tested was aligned with the mechanical axis of the dynamometer. Waist and thigh straps were used to stabilize the subject during the testing session. The tibial force plate on the input arm was positioned 2 inch above the superior border of the medial malleolus.

Start and stop angles were programmed into the Kin-Com's computer after the subject was positioned. Anatomical zero was determined after the subject performed a full active knee extension without the tibial force plate attached. The tibial force plate was then attached to the fully extended leg. The Kin-Com's goniometer was calibrated to read this position as anatomical zero. The subject's leg was then lowered to 0° as read by the Kin-Com's goniometer and was used as the starting position for eccentric quadriceps contraction and stopping position for concentric quadriceps contraction. The lower leg was then moved

to the 90° position as read by the Kin-Com's goniometer, and this was used as the starting position for concentric quadriceps contraction and stopping position for eccentric quadriceps contraction. Each subject was required to generate an initial threshold force of 25 N against the input arm to activate the Kin-Com's Servo mechanism. Gravity correction was performed for each subject with the knee in a position of full extension. With the subject in a relaxed position, the knee was then moved passively into flexion as the Kin-Com automatically adjusted for gravity.

Subjects were familiarized with the procedures that were used to activate the Kin-Com's input arm for alternating concentric and eccentric quadriceps contraction, and likewise, to the standardized verbal commands used during the testing session. The verbal commands were consistent with each subject and also during all the test trials. Each subject was given four submaximal quadriceps contractions for familiarization prior to testing. A rest period was provided to each subject prior to the test procedure. The rest period varied accordingly for each subjects' subjective feelings of full quadriceps recovery following the practice trials. The concentric contractions were performed first from a starting angle of 90° of knee flexion. Once the knee reached terminal extension (0°), the eccentric contractions were then performed. The testing session consisted of three maximal, alternating concentric/eccentric quadriceps contractions with and without patellofemoral brace application. The testing procedure for data collection followed the same format used in the practice session with the order of conditions randomized. Subjects were encouraged to exert a maximum effort during each contraction condition.

2.3. Electromyographic assessment

The EMG electrode placement sites were identified and prepared in the following manner. The subject's VMO and VL of the sampled limb were identified while performing a maximal isometric quadriceps muscle contraction. The centers of the VMO and VL muscle bellies were prepared by shaving the area and scrubbing with isopropyl alcohol and sterile gauze to reduce myoelectrical impedance. The centers of the electrodes were placed 3.0 cm apart and secured with clear tape and an elastic bandage and were placed along the longitudinal axis of the muscle fibers (Fig. 2). The two ground electrodes were positioned over the bony prominence of the medial and lateral malleoli, with the skin surface prepared in the same manner as the electrodes over the VMO and VL. The KC/EMG processing system (Chattex Corporation, Chattanooga, TN) was calibrated as outlined by the manufacturer's operations manual prior to each sub-

ject's test session. Raw EMG signals were collected at a sampling frequency of 1000 Hz, pre-amplified with a 1 000 000:1 gain pre-amplifier and processed through analog to digital conversion. The full wave rectified EMG activity (mV) was integrated (IEMG) and stored on an IBM microprocessor and were analyzed only over the 10–35° arc of motion. This was done for three reasons: (1) to exclude from analysis the myoelectrical activity needed to initiate movement of the limb and to accelerate the limb to the target angular velocity; (2) the potential for subluxation and dislocation occur at this range of motion of knee flexion; and (3) to maintain a consistent value for range of motion in order to compare the IEMG activity between the experimental conditions. A three-way ANOVA with repeated measures was used to detect significant differences between the following three experimental conditions: (1) brace application (with vs. without); (2) contraction type (concentric vs. eccentric); and (3) muscle (VMO vs. VL). A pre-set alpha level of $P < 0.05$ was used for statistical significance. (Fig. 1)

3. Results

The results from this study demonstrated significant main effects for IEMG activity for each of the three conditions but there were no two-way or three-way interactions that were found to be significant. The means and standard deviations for the three conditions are presented in Table 1. The overall IEMG activity for the VMO was significantly greater than the VL ($F_{1,15} = 17.55$, $P < 0.05$), the concentric muscle contraction was significantly greater than the eccentric muscle contraction ($F_{1,15} = 18.18$, $P < 0.05$) and the non-braced condition was significantly greater than the braced condition ($F_{1,15} = 4.86$, $P < 0.05$).

4. Discussion

The major findings from the present study indicate that the IEMG of the knee extensor muscles during isokinetic exercise was significantly lower following the application of the patellar brace. In addition, it was also found that the IEMG for the VMO was significantly greater than the VL during the testing procedure. The results from this study appear to demonstrate that patellar bracing may affect neuromuscular activation of the quadricep muscles during isokinetic knee extension. The decrease of overall IEMG activity following application of the patellar brace may contribute to a reduction in symptoms by reducing abnormal patellar tracking induced by a stronger muscle contraction.

Since IEMG activity was recorded and analyzed through a limited range of motion in this study (10–35°), definitive conclusion regarding the effects of
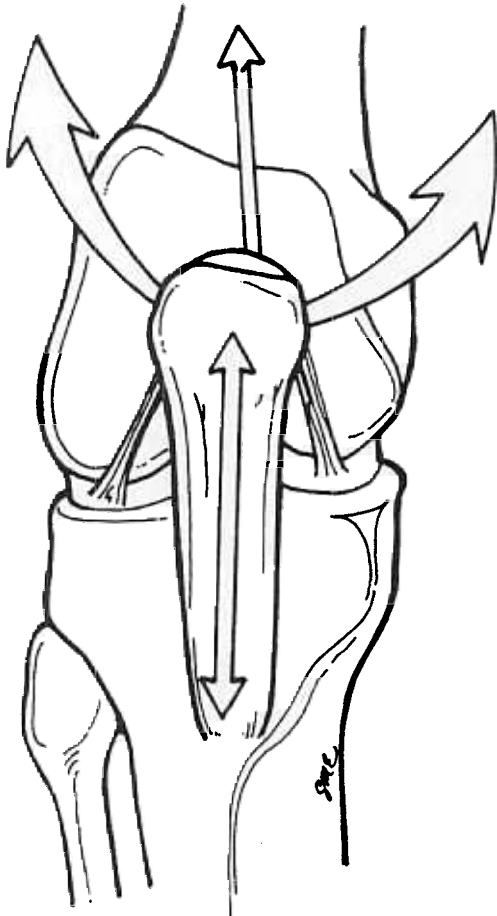
Fig. 1. Dynamic pull of the VMO and VL muscles of the quadriceps mechanism. (Reprinted with permission from Ciccotti MG, Kerlan RK, Perry J, Pink M. An Electromyographic Analysis of the Knee During Functional Activities. II. The Anterior Cruciate Ligament-deficient and -reconstructed Profiles. Am J Sport Med. 1994;22(5):651–658.)

patellar bracing on patella contact area with the femur are not warranted. The patella contacts the articular surface of the trochlea at 20–30° of knee flexion. Patellofemoral contact is continuous from the medial to the lateral facets and begins distally on the patella and progresses to the proximal pole by 90° of flexion. Flexion past 90° induces contact of the odd facet. As the contact zone moves proximal to the patella, the contact area increases. However, increased contact area helps to distribute and disperse this force [2].
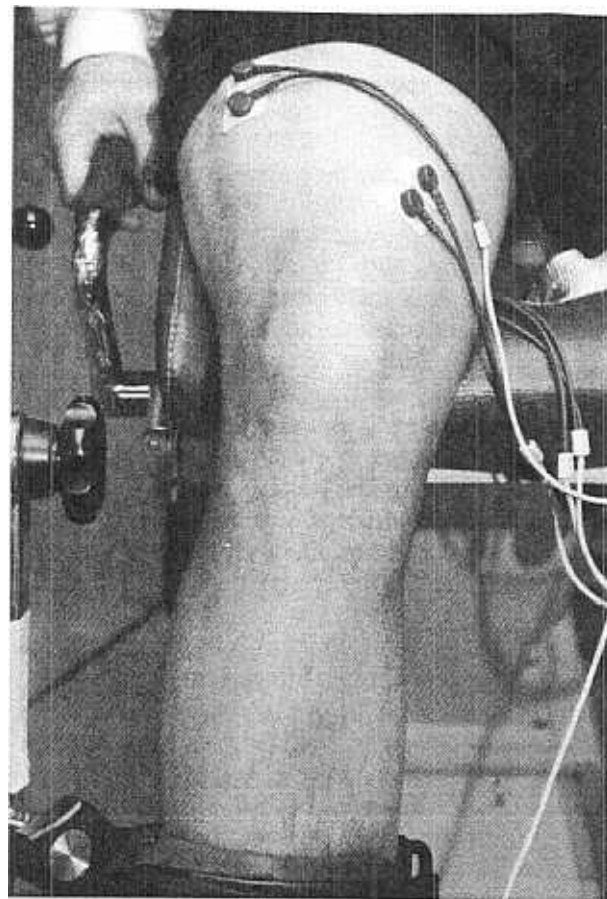

Fig. 2. Isokinetic and EMG preparation for the VMO and VL muscles.

Previous investigators have concluded that the application of a dynamic patellar brace with a lateral buttress was beneficial in alleviating symptoms in patients with patella subluxation [15]. Although the present study did not include a subjective evaluation of brace application, the findings reported appear to be consistent with other studies. Palumbo [15] reported a 93% alleviation of symptoms in the patients treated with a dynamic patellar brace with a lateral buttress and concluded that the brace was beneficial in conjunction with a strict VMO rehabilitation program in those patients with patella subluxation. Similarly, Levine [11] reported good results with a patellar tendon brace he developed which encircles the leg

Table 1

EMG activity (mV) of the VMO and VL by exercise condition (concentric and eccentric) and brace condition

	Concentric[a]		Eccentric	
	Braced	Non-braced	Braced	
VMO[b]	823.44 ± 314.18	874.88 ± 354.77	539.56 ± 279.12	660.12 ± 409.86
VL[b]	577.31 ± 205	574.75 ± 228.97	372 ± 144.36	397.75 ± 147.15

VMO, vastus medialis oblique; VL, vastus lateralis.

[a] EMG activity greater during concentric contraction than eccentric contraction under each condition ($P < 0.05$).

[b] VMO EMG activity greater than VL under each condition ($P < 0.05$).

below the patella and suggested that the brace may alter the mechanics of the patella via repositioning. Lysholm [13] proposed that a patella brace with a lateral buttress may be able to compensate for a malalignment of the patellofemoral joint. The results from the present study may offer a possible explanation that partly accounts for the successful results reported by Palumbo [15], Levine [11] and Lysholm [13]. Decreases in neuromuscular activation observed from the present study may result in the reduction of muscular tension thereby reducing pain causing patellofemoral joint forces. Alternatively, the mechanical support provided by the lateral buttress during isolated knee extension exercise may provide a 'guide' for patellar tracking which may reduce the need for quadriceps activation. However, the present study did not attempt to prove the possible relation between the mechanical action of the patella following brace application and quadriceps activation.

The present study demonstrated that activation of the VMO was greater than the VL during both modes of contraction (concentric and eccentric). This finding appears to be in conflict with that of Voight et al. [18] who evaluated the reflex response times of the VMO and VL to a patellar tendon tap using electromyography in normal subjects and also subjects with extensor mechanism dysfunction. It was reported that the VL fired significantly faster than the VMO in patients with extensor mechanism dysfunction, and therefore suggested that patients with extensor mechanism dysfunction may be demonstrating a neurophysiological motor control imbalance. It is important to note that subjects in the present study were tested as they were identified, and therefore, were not discriminated on previous rehabilitation protocols. Since VMO strengthening has been widely accepted as an integral part of the treatment protocol, the increase in VMO IEMG activity observed in the present study may have partly been a function of previous rehabilitation. Sczepanski et al. [17] investigated the effects of arc of motion, angular velocity, and contraction type on the VMO:VL Absolute Averaged EMG (AAEMG) ratio. The results of their study indicated that the VMO:VL AAEMG ratio was affected by angular velocity of the isokinetic exercise, and therefore, suggested that isokinetic exercise may be an effective means of altering the muscular imbalance between the VMO and VL in patients with patellofemoral malalignment [12]. Future considerations should be directed towards the effect of isokinetic strengthening or other forms of rehabilitation exercises on changes in neuromuscular activation patterns of the quadriceps muscles.

Although the present study did not investigate isokinetic force differences between the different modes of contraction, a significantly greater activation of the quadricep muscles were found during the concentric contraction as compared to the eccentric contraction. These findings appears to be in agreement with others [9,19]. Westing et al. [19] found significantly lower EMG activity (7–31%) under eccentric loading of the quadriceps as compared to velocity matched concentric loading. Likewise, Komi et al. [9] reported that EMG activity remained at very low levels under eccentric loading of the quadriceps muscles as compared to higher activity during concentric contractions. More recently, however, Ghori et al. [4] reported no significant differences in EMG activity for the quadriceps between concentric and eccentric isokinetic exercise performed at 30°/s and subsequently concluded that there is no fixed relationship between EMG activity of the VL and quadriceps torque during maximal concentric and eccentric contractions. It has been established that under concentric contractions, the generated force is the result of the contractile elements of the muscle whereas the elastic and non-contractile tissues of muscle increase their role in force production during eccentric movements [8]. The possibility of a relationship between eccentric muscle activation and patellofemoral pain and/or bracing, however, is beyond the scope of the present study and therefore warrants further investigation.

5. Summary

The clinical implication from this study is that neuromuscular activation of the quadriceps muscles appear to be lowered following the application of a patellar brace with a lateral buttress during isokinetic knee extension exercise. However, it is still not yet known if this decreased activation contributes to an alteration in patellofemoral joint biomechanics and patellar alignment. Future research should focus on the relationship between objective measures of neuromuscular and articular mechanics and function with subjective feelings of comfort that may be associated with brace application. If such a positive relationship does exist, patellar bracing may allow the inclusion of isotonic and isokinetic exercises in a rehabilitation program and therefore, allow an earlier resumption of recreational and athletic activities. The present study appears to suggest that isokinetic knee extension exercise may be affected following the application of a patellar brace in patellofemoral pain patients that is independent of muscle (VMO or VL) and mode of contraction (concentric or eccentric).

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