MECHANICAL RESPONSES to HIP VERSUS KNEE INDUCED MUSCLE FATIGUE IN PATELLOFEMORAL PAIN SYNDROME

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Abstract

Background: Impaired skeletal muscle endurance may be an important causal factor in the development of patellofemoral pain syndrome (PFPS). However, there is lack of information regarding the effect of hip versus knee muscle fatigue on isokinetic parameters, and myoelectric activity of hip and knee muscles in these patients. **Purpose:** The study was conducted to investigate the effect of hip abductors versus knee extensors fatigue protocol on knee proprioception, hip and knee muscle strength and their myoelectric activity in patients with PFPS. **Methods:** Fifteen female patients with PFPS participated in the study. They were tested randomly under two fatiguing conditions; hip abductors and knee extensors fatigue protocols. Isolated muscle fatigue of two muscles was induced isokinetically on the affected side in a two separate sessions with a rest interval of at least three days. After determining peak torque, patients performed continuous maximal concentric-eccentric contraction of the selected muscle until the torque output dropped below 50% of peak torque value for 3 consecutive repetitions. Knee proprioception, eccentric hip abductors' peak torque, eccentric knee extensors' peak torque, EMG ratio of vastusmedialisobliquus (VMO) / vastuslateralis (VL), and EMG activity of gluteus medius (GM) muscle, were recorded before and immediately after each fatigue protocol using the Biodex Isokinetic system and EMG Myosystem. **Results:** Two-way within subject MANOVA revealed that eccentric knee extensors' peak torque decreased significantly after hip abductors fatigue protocol compared to pre fatigue condition ($p<0.05$). On the other hand, there was no statistically significant difference in the eccentric hip abductors' peak torque after admitting knee extensors fatigue protocol ($p>0.05$). Moreover,no significant difference was found in knee proprioception, EMG ratio of VMO / VL, and EMG activity of GM muscle, after either hip or knee fatigue protocol ($p>0.05$). **Conclusion:**A hip focused rehabilitation program may be beneficial in improving knee function through correcting faulty kinematics and hence decrease knee loading in patients with PFPS.

Keywords: Mechanical Responses, Muscle Fatigue, Knee Proprioception, Electromyography, Patellofemoral Pain Syndrome.

Introduction

Patellofemoral pain Syndrome (PFPS) is defined as diffuse anterior or retropatellar knee pain exacerbated by activities such as stair climbing, prolonged sitting, kneeling, running and squatting. It is apathology in which patella is translated or tilted laterally leading to alteration in patellofemoral contact pressure.

Pathomechanics

Several risk factors may lead to Patellar mal-alignment such as proximal factors (Hip muscle weakness) and Localized factors (Muscle imbalance). Biomechanically, the pennation angle of the VMO muscle is well suited to apply a medially directed force to the patella. On the other hand,Vastusmedialisobliquus muscle has low contraction velocity and always is inhibited due to Q angle. Additionally, Vastuslateralis muscle has large contraction force and high contraction velocity. Recently, it was reported that functional mal-alignment does not arise in the knee joint but rather by internal rotation and adduction of the femur due to weakness of hip external rotators and abductors. (Petersen et al., 2013).Weak hip abductorsleads to lateral translatory motion (lateral patellar mal-tracking). Weak hip external rotators leads to lateral angular motion (lateral patellar tilt).

Proprioception

The proprioceptive system contributes to JPS, joint motion sense, and kinesthesia. This includes the sensations of muscle length and tension, joint angles, and changes in these angles (Kars et al, 2009). Proprioception is an action-reaction mechanism. voluntary and spinal reflexes are important in sending messages to the muscles to react and protect the body. Proprioception is important in maintaining joint

stability. Thus, if the muscles are fatigued, voluntary and spinal reflex time increases and proprioception performance decreases, resulting in incorrect joint position during weight bearing activity and decreased joint stability and an increased in the probability of injury (Kruger et al, 2004). (through increase joint reaction force).

Also, Proprioception impairment may lead to several musculoskeletal disorders by disrupting the control of movement leading to abnormal stresses on tissues. It was reported that, the onset of VMO relative to VL is usually delayed in patients with PFPS due to abnormal proprioception from the surrounding articular

Muscle fatigue

Muscle fatigue is defined as the decline in force output capacity after repeated muscle contractions (Hossein et al., 2013). It has been postulated that, increased fatigability followed by muscle weakness is one of the primary symptoms of patients with different musculoskeletal disorders. Therefore,our purpose of the current study was to investigate the effect of induced hip and knee muscle fatigue protocols on knee proprioception, isokinetic peak torque and myoelectric activity of knee extensors and hip abductors in patients with patellofemoral painsyndrome.

Methods

This study involved 15 female patients with PFPS. All patients had anterior or retropatellar knee pain after performing at least two of the following activities: prolonged sitting, stair climbing, squatting, running, kneeling, hopping/jumping, ascending or descending stairs, and deep knee flexion. All patients had Q angle ranged between 20° -22°.

2- Positive signs of anteirior knee pain during initial physical examination pain following isometric quadriceps contraction (Clarke's sign).

3- Pain following compression of the patella against the femoral condyles (Patellar grind test).

4- Functional performance ranged between 65-84 (according to Kujala questionnaire) (Scale designed to measure function in the individuals with anterior knee pain)

5- Knee pain ranged from 3 to 10 according to 10 cm visual analogue scale (VAS)

(One of the frequently used methods of assessing pain in the clinical environment)

Instrumentation:

1- Isokinetic dynamometer

Biodex was used to induce knee extensors', hip abductors' and external rotators' fatigue protocol, measuring knee joint proprioception and the eccentric peak torques of the selected muscles at an angular velocity 60 degree/sec.

2-Electromyography apparatus (EMG)

EMG apparatus was used to DETECT changes in the interference patterns of the EMG of the examined muscles (VMO, VL, and GM muscles).

Procedures

This study involved a within-subject experimental design in which one group of patients processing under both fatiguing conditions

At first, he recording data sheet was filled in for each patient then each patient was instructed to pick up one of two papers from a container for random selection. These two papers represent the two fatiguing protocols (hip or knee fatigue protocols).

If the chosen fatigue protocol was the hip abductors: The following pre fatigue procedures were done.

Firstly:

EMG electrodes were placed at the motor points of the tested muscles (VMO, VL, and GM muscles). VMO electrodes were placed approximately 4 cm superior and medial to the superomedial border of the patella. Also, it was oriented at 50-55o to the reference line (A line drawn from ASIS to center of patella). The VL electrodes were placed 10 cm superior to the superolateral border of the patella at approximately 15o to the reference line. For GM muscle, electrodes were placed half the distance between the iliac crest and greater trochanter.

Secondly:

Patients were asked to ascend and descend two steps of 20 cm height, 55cm length, and 25cm width starting with the tested limb followed by the contralateral during ascending and descend first with untested limb.

Then, Knee proprioception was measured at angle 45 degree of knee flexion. Patients were blindfolded. The patient's leg was placed at a starting angle of 90o knee flexion for each trial. Then it was moved passively to the tested angle (45o of knee flexion) by the dynamometer. Patient was asked to concentrate on the sensation of the presented angle for 5-seconds. The leg was then returned passively to the starting position by the examiner. After 5-seconds rest period the patient was attempted to actively reproduce the presented joint angle for another five seconds. Three trials were performed and the average was taken for statistical analysis. Knee extension strength test was performed with concentric-eccentric mode of contraction. Patients were instructed to perform five maximal concentric –eccentric contractions at an angular velocity 60 degree per second

Just before conduction of hip fatigue protocol, hip abductors' eccentric peak torque was recorded. For measuring Hip abductors' peak torque, (five repetitions of concentric/eccentric contractions for hip abduction and external rotation were performed).

Fatigue protocol

Fatigue protocol = At first, three trials of sub-maximal and three of maximal contractions were performed. After a 60 seconds rest and in order to determine peak torque, three repetitions of maximal concentric-eccentric contraction were performed with no rest in between. The highest torque achieved during the patients were instructed to perform continuous maximal concentric-eccentric contractions of the target muscle at 60^{o}/s until the torque output dropped below 50% of the peak torque for three consecutive contractions. Three repetitions were considered as peak torque. After two-three minutes, patients were instructed to perform continuous maximal concentric-eccentric the same procedures were done after knee fatigue protocol. Immediately after performing the fatigue protocol, knee proprioception was measured first, then knee extensor and hip abductor muscle strength and finally EMG activity was recorded again.

Statistical analysis

In the current study, two independent variables and five dependent variables were tested**.** Two independent variables = first one was fatigue type which has two levels (hip and knee fatigue). Second independent variable was fatigue time which has two levels (pre and post fatigue). The five dependent variables (knee proprioception, eccentric hip abductors' and external rotators' peak torques, eccentric knee extensors' peak torques, EMG ratio of VMO/VL, and EMG activity of GM muscle).

- This was conducted through assessing the level of significance of normality tests, skewness and kurtosis, and extreme

- Once data were found not to violate the normality assumption, after that, appropriate statistical test was conducted (Two-way within subject MANOVA).Multiple pairwise comparison tests. Level of significance was set at .05.

Results

Regarding knee proprioception, two way within subject MANOVA revealed that there was no statistically significant difference in knee proprioception between pre and post fatigue conditions after either hip or knee fatigue protocol. As noted after hip fatigue protocol, increase in absolute angular error was found but not reach statistical significance. P value was 0.07. Additionally, regarding eccentric knee extensors' peak torque, there was a statistically significant reduction of eccentric knee extensors' peak torque at both hip and knee fatigue protocols.

Concerning eccentric hip abductors' peak torque, there was a statistically significant reduction of eccentric hip abductors' after hip fatigue protocol compared to the prefatigue condition. On the other hand, no significant difference was found in the eccentric hip abductors' peak torque between pre and post knee fatigue conditions.

Two way within subject MANOVA indicated that there was, no statistically significant difference was found after eitherVMO/VL EMG ratio hip or knee fatigue protocol. However, when the EMG activity of each muscle was analyzed individually, the results revealed significant increase in their activity.Regarding EMG activity of GM muscle, no statistically significant difference was found between pre and post fatigue conditions after either hip or knee fatigue protocol

Discussion

Knee proprioception

The increase in absolute angular error noted in knee proprioception after fatigue protocol of hip abductors might be attributed to

- Greater lateral quadriceps force. This will lead to Increase retropatellar stress and Peripatellar plexus dysfunction leads to impaired proprioception through affecting mechanoreceptors.
- **The insignificant difference in knee proprioception after conducting knee extensors fatigue protocol may be due to**

1- Localized fatigue protocolused (General fatigue which affects other mechanisms in the proprioceptional pathway).

2- Modulating the number and/ or firing rate of active motor units (2-modulating the number and/ or firing rate of active motor units through adding new unfatigued large motor units to prevent the decline of force generating capacity.

3- Agonist muscle fatigue (It was reported that fatigue of hamstring would lead to decreased sensory output of the muscle spindles associated with the hamstrings. Since muscle spindles are stretch receptors, decreased afferent output of the sensory organs in the posterior compartment of the thigh should lead to a decrease in proprioception, in particular joint position sense, with movement into extension.

Eccentric knee extensors' peak torques

Statistically significant reduction in eccentric peak torque of knee extensors after hip abductors fatigue might be attributed to:

1- Central fatigue: Central fatigue, prolonged exertion used in the current fatigue protocol is believed to cause both peripheral and central elements

of neuromuscular control; referred to as peripheral fatigue and central fatigue. Central fatigue might play an important role in the reduction of the firing frequency of the motor units.

2- Alteration in hip mechanics in the form of increased hip adduction and internal rotation of the femur leads to increase peak contact pressure on the posteirior patellar surface. Increase stress leads to increase pain. Pain causes inhibition of the alpha motor neuron and prevents the full activation of quadriceps specifically; VMO muscle compared with other vastus components. Pain leading to reduced force production (torque).

Eccentric hip abductors' peak torques

1- The insignificant difference in hip abductors' strength following fatigue of knee extensors might have occurred through: Insignificant reduction in eccentric hip abductors' peak torque might be due to increase firing level of gluteus maximus muscle.. Since the exercise strngth testing in the current study measured from open kinetic chain, the main role of gluteusmaximus is to control hip adduction and internal rotation instead ofgluteus medius which is required mainly to stabilize frontal plane motion from weight bearing position.

2- Also, during seated fatigue position, the rectus femoris is functionally weaker. It is biarticular muscle, acting as a flexors on the hip joint and as extensors on the knee muscles. During knee extension fatigue protocol, it acts mainly on the knee joint and isolated on the hip joint. Therefore, an ineffective transfer of torque from the knee to hip joint leads to insignificant fatigue effect.

In the current study, fatigue of hip abductors affected knee extensor's strength. On the other hand, fatigue of knee extensors did not have effect on hip muscles. This could relate to different responses of these muscles to fatigue.

Hip abductors are stabilizing muscles which are prone to weakness and inhibition. Therefore, they are less activated in most functional movement's patterns, and fatigue easily during dynamic activities. On the other hand, knee extensors are mover groups that readily activated during most functional movements and resistant to fatigue

VMO/ VL EMG ratio

Insignificant difference in VMO/VL EMG ratio might have occurred due to increase EMG activity of both VMO and Vl muscles when analyzed individually. Fatigue leads to increase increase recruitment of additional motor units and increase amplitude of EMG activity. After knee muscle fatigue.It was found that, rectus femoris (RF) muscle fatigued to agreat extent than VMO and VL muscles. Therefore, EMG activity of VMO and VL increased significantly to compensate great fatigue effect of RF muscle.Meanwhile, after hip fatigue the cause of increased activity of both VMO and VL muscles was mainly due to decreased knee extensor muscle strength. Two mechanisms of decreased knee extensors strength after hip muscle fatigue were found. Firstly, Increase knee valgus after fatigue of hip abductors was found. Knee valgus angle leads to increased knee abduction ROM which supported by researchers (Dierks et al., 2008; Willson et al., 2008). Increased knee abduction ROM leads to increased knee adduction moment. The quadriceps muscle group generates an abduction moment to resist the internal knee adduction moment. This leads to decreased knee extensor muscle strength. Additionally, EMG activity of VMO and VL

muscles was recorded during ascending and descending stairs. Women tend to land with less knee flexion angle when testing knee kinematics during landing after hip abductor fatigue protocol (Jacobs et al., 2007). Quadriceps extension moment was especially influenced knee flexion angle. This was attributed to the relation of soft tissue length and eccentric tissue tension according to rule of length tension relationship.

EMG activity of the GM muscle

1- The lack of diminished neuromuscular control after hip abductors and knee extensors fatigue protocol might be related to the nature of task performed. EMG activity of GM muscle which was recorded during ascending and descending stairs. Such exercises induce coactivation that is based on the characteristics of closed kinetic chain exercise ((Myers et al., 1999; Timothy et al., 2001). These characteristics include compression of the femoral head within the acetabulum. The stimulation of the articular mechanoreceptors elicits a coactivation response of trunk musculature (Neumann, 2010). Thus, there was no decrease in neuromuscular control of GM muscle post fatigue.

2- Also, Insignificant difference of EMG activity of GM muscle may related to, Lateral trunk lean might be occurred during stair stepping task. Passive moment of stance hip abductors produced as a result of shifting center of mass over the hip joint center. Therefore, the amount of force and activity level was equalized and no significant difference was found