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Literature Review

Recording the vastii muscle onset timing as a diagnostic parameter for patellofemoral pain syndrome: Fact or fad?

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ABSTRACT

Purpose and method: In this literature review, relevant studies on electromyographic (EMG) onset timing of vastus medialis obliquus and vastus lateralis in people with and without patellofemoral pain syndrome (PFPS) were reviewed and discussed.

Conclusion: Studies had used diverse EMG signal processing and testing protocols, also only a half of their findings tended to support the notion that detection of EMG onset of the vastii muscles is diagnostically useful for identifying subjects with PFPS.

1. Introduction

Patellofemoral Pain Syndrome (PFPS) describes the condition of diffuse pain over the anterior aspect of the knee that is exacerbated by functional postures or physical activities such as prolonged sitting and stairs climbing that stress the patellofemoral joint without other identifiable causative pathologies (Cutbill, Ladly, Bray, Thorne, & Verhoef, 1997; LaBotz, 2004). The condition affects approximately 25% of the population at some stage of their lives (McConnell, 1996) with females being more vulnerable than males (Almeida et al., 1999) and the pain can become chronic that lasts for years (Jensen, Hystad, Kvale, & Baerheim, 2007; Souza & Powers, 2008). It is proposed that the PFPS is caused by a combination of intrinsic and extrinsic factors. Most of the intrinsic factors are, reportedly, related to an excessive lateral patellar tracking that leads to undue strain on the retro-patellar subchondral bone (Draper et al., 2006; Thomee, Augustsson, & Karlsson, 1999). These may include an imbalance between the medial and lateral vastii muscles (Boling, Bolgla, Mattacola, Uhl, & Hosey, 2006), increased Q-angle (LaBella, 2004), hyper-mobile patella (Witvrouw, Lysens, Bellemans, Danneels, & Cambier, 2001), or tightness of the patellar retinaculum (Fulkerson, 1983). Extrinsic factors that commonly contribute to PFPS include poor form of functional movements (Powers, 2003), excessive duration or frequency of physical activities (Dixit, DiFiori, Burton, & Mines, 2007).

The delayed onset of vastus medialis obliquus (VMO) relative to vastus lateralis (VL) measured by electromyography (EMG) has received a lot of interests in the field of physical therapy, since some studies have proposed that the onset of VMO to be preceded by VL in patients with PFPS while healthy individuals show the opposite pattern (Grabiner, Koh, & Draganich, 1994; Neptune, Wright, & van den Bogert, 2000; Voight & Wieder, 1991).

Voight and Wieder (1991) are the first researchers who reported that the mechanism for excessive lateral patellar tracking is an imbalance in the activities of VMO relative to VL; the mechanism was evident with VL firing significantly earlier than VMO in the knee-jerk reflex in patients with PFPS. Neptune et al. (2000) reported that the VMO onset prior to that of VL is a feed-forward or open-loop motor control for the VMO to generate adequate medial force to stabilize the patella; otherwise the VL may laterally displace the patella leading to patellar maltracking. If VL habitually fires before VMO, the lateral patellofemoral joint may be overloaded resulting in PFPS (Grabiner et al., 1994).

2. Literature review

The present literature review searched the MEDLINE from 1966; CINAHL from 1982; EMBASE from 1980 to 2008 with the keywords of EMG, vastus medialis, vastus lateralis, anterior knee pain, patellofemoral joint and onset time. That resulted in 54 relevant articles found for the topic. The final selection criteria were to

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include those studies that had conducted clinical experiments with both patient and control groups, and one of the outcome measurements was EMG onset timing of vastii. A total of 12 studies fitted the above criteria and were included in this review.

The EMG recording has been used frequently to study the muscle onset timing and most of the studies were on muscle co-ordination between agonist and antagonist (Engelhorn, 1983; Häkkinen et al., 1998; Liang et al., 2008). There were more than 10 methods for determining the muscle onset by different researchers but for studies that aimed at VMO and VL onsets related to PFPS, only 5 methods were reported in the literature. Since the determination of EMG threshold is vital for muscle onset detection (Hodges & Bui, 1996; Winter, 1984), the following reviews are divided under those methods.

3. Review of previous papers

3.1. Surface EMG onset determined by visual inspection

Voight and Wieder (1991) evaluated knee-jerk reflex response times in 41 normal subjects (17 males & 24 females, mean age: 26) and 16 patients with PFPS (10 males & 6 females, mean age: 25). Absolute reflex response times were visually determined as the time from the electrical signal externally triggered by the tap on patellar tendon to the rising EMG signal of VMO and VL muscles. Their study showed that the VL fired significantly earlier than the VMO in the PFPS group; their VL response times even were significantly faster than that of the normal subjects, whereas the VMO times were not significantly different between the groups. Although the reflex response time could increase with the subject's height, the possible height variation among the subjects was not mentioned in the study.

Witvrouw, Sneyers, Lysens, Victor, and Bellemans (1996) investigated the reflex response time of knee jerk among 80 control subjects (37 males & 43 females, mean age: 18) and 19 persons with PFPS (8 males & 11 females, mean age: 21) by surface EMG. Absolute reflex response time was taken from the tendon hammer tap to the beginning of the EMG signal of VMO or VL leaving the baseline. The authors found that the response time of VMO was significantly shorter than that of VL in normal subjects. While in subjects with PFPS, significant earlier firing of VL was found and a reversal in the firing sequence of VMO was noted on the affected side.

Bevilaqua-Grossi, Felicio, and Leocádio (2008) investigated the knee-jerk reflex response time of VMO, vastus lateralis obliquus (VLO) and vastus lateralis longus (VLL) muscles in 12 women with PFPS (mean age: 22) and 24 asymptomatic females (mean age: 23). Absolute reflex response time was measured from the tap on patellar tendon to the peak electrical response of the VMO, VLO and VLL muscles, respectively. Both groups presented shorter response time for the VMO muscle than for the VLO and VLL muscles, and there was no significant difference in the response times between the groups.

3.2. Surface EMG onset as one standard deviation above the mean of baseline signal

Karst and Willett (1995) examined the onset times of VMO and VL in asymptomatic subjects and subjects with PFPS using knee-jerk reflex, active non-weight and weight bearing knee extension. With 15 symptomatic subjects (6 males & 9 females, mean age: 28) and 12 controls (4 males & 8 females, mean age: 29) participated, both knees were tested in the control group and only the affected knees were tested in the symptomatic group. The EMG onset threshold was set at the amplitude one standard deviation above the mean of the rectified resting baseline signal. The authors did not compare the values of the two groups' absolute onset times of vastii, but rather to use the vastii's onset difference as the VL latency minus the VMO latency for comparison. They concluded that no significant differences were found between the control and symptomatic groups in all three tests.

3.3. Surface EMG onset point as peak amplitude of normalized root-mean square

Sheehy, Burdett, Irrgang, and VanSwearingen (1998) studied surface EMG activity of VMO and VL while 15 asymptomatic subjects (7 males & 8 females, mean age: 26) and 13 subjects with PFPS (7 males & 6 females, mean age: 27) performed ascending and descending stepping. The onset timing of vastii was determined by the peak of normalized EMG signal processed with root-mean square (RMS) at time constant of 50 ms in concentric and eccentric phases. No difference was found between the two groups, between VMO and VL muscle or among ascending and descending phases statistically. However, their use of RMS-signal processing might flatten the raw EMG signal excessively, thus the onset difference between VMO and VL may be diminished.

3.4. Surface EMG onset set as three standard deviations above the mean of baseline signal

Cowan, Bennell, Hodges, Crossley, and McConnell (2001) used an EMG onset identification method in which recorded EMG signal was processed with 50 Hz low-pass filter and rectification; the onset threshold was set as three standard deviations above the mean of baseline signal for minimum of 25 ms. They analyzed the VMO and VL onsets during concentric and eccentric phase of stair stepping in 33 subjects with PFPS (11 males & 22 females, mean age: 27) and 33 controls (13 males & 20 females, mean age:24). A delayed VMO onset relative to VL onset was found in the PFPS group and synchronous onset was noted in the control group. However, the possible over-simplification or distortion of the EMG signal due to the 50 Hz low-pass filter was not discussed in the study.

Using the same EMG method, Cowan, Hodges, Bennell, and Crossley (2002) also examined vastii onsets in toes tipping and heel rising tasks in standing posture for 37 PFPS patients (14 males & 23 females, mean age: 28) and 37 controls (14 males & 23 females, mean age: 24). Onset of VL preceded that of VMO in both tasks in PFPS group while the controls showed synchronous onset of VMO and VL.

Hinman, Bennell, Metcalf, and Crossley (2002) investigated the EMG onsets of VMO activity relative to that of VL in 41 subjects (21 males & 20 females, mean age: 68) with knee osteoarthritis which on radiological examination showed that 80% had patellofemoral involvement, and also compared with 33 asymptomatic subjects (17 males & 16 females, mean age: 68) during stairs climbing. The results of this study showed no difference in the onset timing of VMO and VL in concentric or eccentric phases of quadriceps contraction.

Crossley, Cowan, Bennell, and McConnell (2004) applied the above-mentioned EMG technique to examine 48 subjects with PFPS (17 males & 31 females, mean age: 28) compared with 18 (9 males & 9 females, mean age: 35) asymptomatic subjects' vastii onset times during stance-phases of ascent and decent stair-climbing. They found that almost 50% of symptomatic subjects had delayed VMO onset during ascent or decent stepping. A 50% of the symptomatic and the control group showed synchronous onsets of VMO and VL.

Santos et al. (2008) evaluated the relative onset time difference of VMO, VLO and VLL during isokinetic knee extension and step-climbing in 10 women with PFPS (mean age: 25) and 10 female