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# Surface electrode placement affects the EMG recordings of the quadriceps muscles

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**Abstract**

*Objectives:* This study examined the EMG activities of the medial and lateral vasti muscles with four different surface electrode positions during isometric knee extension and knee perturbation.
*Design:* Repeated measures design.
*Setting:* Orthopaedic rehabilitation laboratory of a university.
*Participants:* Eight able-bodied non-athletic male volunteers.
*Main outcome measures:* The relative onset time difference in milliseconds of vastus medialis obliquus (VMO) and vastus lateralis (VL) during knee perturbation, and the normalized EMG amplitude in root-mean-square ratio of VMO:VL during submaximal isometric knee extension were analyzed using repeated measures ANOVA.
*Results:* Different electrode positions on VL resulted in different VMO-VL onset time ($p = 0.002$) and normalized VMO:VL activity ratios ($p = 0.002, 0.014$).
*Conclusions:* The position of surface electrodes has significantly affected the EMG readings of the vasti muscles. This finding has vital clinical implications for the application of EMG measurement and biofeedback training for the rehabilitation of the vasti muscles.


*Keywords:* Electromyography; Electrode; Knee; Quadriceps muscle

## 1. Introduction

Patellofemoral pain syndrome (PFPS) presents as localized pain, inflammation, muscle imbalance, and instability of any component of the knee extensor mechanism (LaBotz, 2004). The PFPS affects approximately 25% of the population at some stage in their lives (McConnell, 1996) with females being more vulnerable than males (Almeida, Trone, Leone, Shaffer, Patheal, & Long, 1999).

Patients with PFPS usually respond to non-operative treatments and the outcome is usually assessed with the level of pain, patellar alignment, soft-tissue flexibility, muscle activation, and coordination (Post, 2005). The vastus medialis obliquus (VMO) and vastus lateralis (VL) muscles have different morphological, functional, and neuromotor characteristics (Crossley, Bennell, Green, & McConnell, 2001; Lieb & Perry, 1968; Ng, 2002). The two muscles work synergistically to provide the dynamic stabilizing force on the patella during knee extension and imbalance between the VMO and VL would disturb the dynamic stability of patella. Clinically, weakness of the VMO would result in excessive lateral tracking of patella, which has been regarded as a common cause of PFPS (Herrington, 1998; McConnell, 1996). Furthermore, some studies had reported that persons with PFPS had reduced VMO:VL electrical

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activity ratio and delayed VMO onset when compared with normal controls (Mariano & Caruso, 1979; Souza & Gross, 1991; Tang, Chen, Msu, Chou, Mong, & Lew 2001; Voight & Wieder, 1991; Witvrouw, Sneyers, Lysens, Victor, & Bellemans, 1996).

The relative activity of VMO and VL has been studied in the past. Souza and Gross (1991) reported the normalized VMO:VL activity ratio in healthy subjects was approximately 1:1 during isometric knee extension, whereas Boucher, King, Lefebvre, and Pepin (1992) reported the ratio to be approximately 2:1 for asymptomatic subjects in static terminal knee extension. Tang et al. (2001) demonstrated that the ratio was less than 1 for normal subjects at the end range of isokinetic knee extension.

In terms of the temporal parameters of the vasti muscles, Voight and Wieder (1991) and Witvrouw et al. (1996) reported that VL fired significantly earlier than VMO in the knee jerk reflex in patients with PFPS, which was in contrast to the findings of Karst and Willett (1995) who reported no difference in VMO-VL contraction timing in the knee jerk reflex in both normal subjects and those with PFPS. Powers, Landel, and Perry (1996) also found that the VMO:VL activity ratio and the VMO-VL relative onset time were not different between patients with PFPS and the normal controls during walking or climbing stairs.

Some researchers had attempted to develop specific strengthening exercises for the VMO. Hanten and Schulthies (1990) and Laprade, Culham and Brouwer (1998) reported that VMO was more active than VL during isometric knee extension with hip adduction and tibial internal rotation. Lam and Ng (2001) and Ng and Man (1996) reported that VMO was significantly more active than VL with some knee flexion and internal hip rotation. However, Mirzabeigi, Jordan, Gronley, Rockowitz, and Perry (1999) and Reynolds, Levin, Medeirosm, Adler, and Hallum (1983) did not support the concept of selective recruitment of VMO over VL in physical training.

The discrepancies of the above findings could be due to the electrode placements not being comparable among these studies. Boucher et al. (1992) placed an electrode over the motor point of VL at the mid-thigh level of 15 cm above the upper border of patella. Gilleard, McConnell, and Parsons (1998) placed the VL electrode at 10 cm above the patella. Cram and Kasman (1998) recommended that the electrode for the VL muscle should be at 5 cm above the knee. Conversely, the electrode placement for VMO was more consistent among previous studies as most reported the position to be 3 or 4 cm above the supero-medial corner of patella (Cram & Kasman, 1998; Gilleard et al., 1998). In light of the diverse positioning of the VL electrode and the lack of information on the effects of surface electrode positioning on the EMG recording, there is a need to examine if the electrode positioning would affect the EMG measurements. This has vital clinical implications because imbalanced VMO:VL EMG activity ratio or VMO-VL onset time are regarded as contributing factors of PFPS, the effect of electrode positioning must be considered in order to make accurate assessments. Therefore, the present study was conducted to investigate the effects of different surface electrode placements on the VMO:VL magnitude ratio and VMO-VL relative onset timing.

## 2. Methods

### 2.1. Subjects

Eight able-bodied non-athletic males aged between 24 and 35 years (mean 28.1 years) were recruited. Subjects with history of lower limb operations or injuries that required treatments in the past 6 months were excluded. The study was reviewed and approved by the Human Ethics Sub-committee of The Hong Kong Polytechnic prior to data collection. All subjects were asked to refrain from vigorous physical activities the day before the study.

### 2.2. EMG recordings

Skin on the distal thigh of the dominant leg was shaved and cleansed with methylated spirit and skin preparation gel (NuPrep, DO Weaver & Co., Aurora, CO, USA). The skin impedance was checked with an impedance meter (1089MKIII, UFI, Morro Bay, CA, USA) and a value of less than 50 kΩ was deemed acceptable (Hewson, Hogrel, Langeron, & Duchene, 2003).

After the skin preparation four single-differential EMG electrodes (Myoscan, Thought Technology, Montreal, Que., Canada) were placed over the VMO and VL with disposable/adhesive circular snap electrodes (Multi Bio Sensors, El Paso, TX, USA). The electrode for VMO was placed at a point 4 cm above the supero-medial corner of patella, whereas three electrodes were placed over VL at 5, 10, and 15 cm above the supero-lateral corner of patella (Fig. 1). The orientations of the VMO and VL electrodes were 55° and 15° to the longitudinal axis of femur, respectively (Lieb & Perry, 1968).

The electrodes were connected to a battery-powered encoder (SA9404P, Thought Technology, Montreal, Que., Canada) with a sampling rate of 1984 Hz. The encoder was fed to a digital signal processing board (DSP, version 2, Thought Technology, Montreal, Que., Canada) installed on a personal computer. Data acquisition software (V1.52 Ergonomic Suite, Thought Technology, Montreal, Que., Canada) was used to