



# Cutaneous stimulation from patella tape causes a differential increase in vasti muscle activity in people with patellofemoral pain

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## Abstract

Patella taping reduces pain in individuals with patellofemoral pain (PFP), although the mechanism remains unclear. One possibility is that patella taping modifies vasti muscle activity via stimulation of cutaneous afferents. The aim of this study was to investigate the effect of stretching the skin over the patella on vasti muscle activity in people with PFP. Electromyographic activity (EMG) of individual motor units in vastus medialis obliquus (VMO) was recorded via a needle electrode and from surface electrodes placed over VMO and vastus lateralis (VL). A tape was applied to the skin directly over the patella and stretch was applied via the tape in three directions, while subjects maintained a gentle isometric knee extension effort at constant force. Recordings were made from five separate motor units in each direction. Stretch applied to the skin over the patella increased VMO surface EMG and was greatest with lateral stretch. There was no change in VL surface EMG activity. While there was no net increase in motor unit firing rate, it was increased in the majority of motor units during lateral stretch. Application of stretch to the skin over VMO via the tape can increase VMO activity, suggesting that cutaneous stimulation may be one mechanism by which patella taping produces a clinical effect.

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*Keywords:* Patellofemoral; Vastus medialis obliquus; Cutaneous stimulation; Motor unit activity; Taping

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## Introduction

The application of tape to the skin over the patella has been shown to contribute to a significant and immediate reduction in patellofemoral pain (PFP) [2,16,27,32,38]. Patella taping was originally proposed to decrease pain by altering patella mechanics [27], however there is debate in the literature as to whether this occurs [2,38]. Alternatively, the clinical effect of patella taping may be due to changes in activity of the vasti muscles.

Patellofemoral pain is a common musculoskeletal condition involving a spectrum of articular cartilage

changes to the undersurface of the patella [3], generally caused by excessive or abnormal contact of the articular surface with the femoral condyles. This is believed to be due to abnormal patella tracking which can result in abnormal forces and pressures at the patellofemoral joint which may eventually lead to pain [18]. A number of mechanical factors are considered to contribute to PFP, such as increased Q or quadriceps angle, femoral rotation, femoral neck anteversion, tight lateral structures, excessive foot pronation, patella alta, variation in patella shape, abnormal patellar positioning, joint laxity or patella instability and VMO insufficiency or wasting [14]. Research has focused previously on the effects of the muscular and osseoligamentous contributions to patellar tracking. However, more recently, the importance of the neural control system has been highlighted. A number of recent studies have provided

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evidence of an imbalance in the activation of the timing of VMO and VL in people with PFP. For example VMO activity has been found to be delayed relative to VL in a stair stepping task in individuals with PFP [10], and when reacting to a postural perturbation [11]. However, some other studies have failed to find a difference [22,33,36].

It appears unlikely that mechanical changes produced by application of tape can specifically produce the clinical effects seen, as a number of studies have failed to find significant changes in patella position with taping. For instance, in a radiographic study by Bockrath et al. [2], although patella taping was found to contribute to a dramatic reduction in pain, it was not associated with change in patella position. Somes et al. [38] found that taping reduced pain by 45% and improved medial tilt of the patella, but had no effect on patella glide. Thus the pain relief from taping may be due to mechanisms other than mechanical or positional changes.

One outcome of taping that has been studied extensively is the effect of various types of knee braces, bandages and taping on joint proprioception. For example, Lephart et al. [24] found improvement in knee joint proprioception of subjects after repair of the anterior cruciate ligament, following application of a neoprene sleeve. These authors suggested that the improvement was due to augmented afferent input via enhancement of cutaneous stimulation. Barrett et al. [1] used a similar explanation for the improvement found in people with osteoarthritis of the knees with use of an elastic bandage. In contrast, a study on the effects of taping on knee joint proprioception in healthy subjects [4] found no differences between tape and no-tape conditions in their proprioceptive tests. However, when the subjects were graded as having good or poor proprioception, taping was found to significantly improve angle reproduction in those with large initial errors on the proprioceptive tests. These data appear to indicate that improvements may only be detected when there is a deficit initially.

Alternatively, the effects seen with patella taping may be due to alteration of muscle activity. The co-ordination of the vasti muscles is important in control of patella tracking, as Neptune et al. [29] proposed from simulation studies that a delay in VMO onset of only 5 ms can result in a significant increase in patellofemoral joint loading, which can lead to PFP. A number of studies have investigated the effect of taping on temporal and spatial characteristics of vasti muscle activity. For example, Cowan et al. [9] reported a change in timing of vasti muscle activity during a stair stepping task following the application of tape. In subjects with PFP, taping caused the onset of VMO EMG activity to occur earlier relative to VL. This did not occur in painfree subjects, or with placebo taping which was applied vertically over the patella without tension.

Studies of EMG amplitude of VMO and VL have been inconclusive with some studies reporting a change with tape [30,31] while others have not [5,8,35]. However, most tasks involve functional movements which inherently have large variability and studies may not have had the statistical power to detect a difference.

Despite evidence to support the change in vasti muscle activity associated with taping, the mechanism of this change remains unclear. One possibility is that the stimulation of cutaneous afferents via tape leads to changes in muscle activity.

Previous research has shown a relationship between cutaneous afferent stimulation and motor unit firing. McNulty et al. [28] demonstrated that firing of a single cutaneous afferent influences muscle activity in the hand. Garnett and Stephens [15] found a change in the order of recruitment of motor units of the dorsal interosseous muscle during cutaneous stimulation of the hand. Thus we hypothesised that cutaneous stimulation from stretch of the skin over the patella and VMO may induce changes in vasti muscle activity. There is preliminary evidence that stretch of the skin over the patella may lead to changes in vasti muscle activity in painfree individuals (Gerlach et al., unpublished observations).

The purpose of this study was firstly, to determine whether there is a change in the firing rate of single motor units of VMO in people with PFP when stretch is applied to the skin over the patella. Secondly, we aimed to investigate whether there is a change in relative EMG amplitude of the vasti muscles when stretch is applied to the skin over the patella in this population. Thirdly, we investigated whether the effect of stretch of the skin over the patella was specific to the direction of stretch.

## Methods

### Subjects

Eight subjects with patellofemoral pain syndrome (Six females, two males, age  $22 \pm 3.04$ , weight  $67 \pm 7.29$ , height  $172 \pm 10.84$ ) participated in the study. These subjects were included if they had a history of anterior knee pain with a duration of symptoms greater than 3 months and of an intensity sufficient to limit function or cause the individual to seek intervention. The diagnosis of PFP was based on the clinical criteria of Brukner and Khan [3] including diffuse anterior knee pain which may be aggravated by at least two of the following activities: squatting, kneeling, stair climbing and prolonged sitting. In addition, they were to have an average pain level of 3 cm or more on a 10 cm visual analogue scale (VAS), and have an insidious onset of symptoms unrelated to a traumatic incident. All participants were aged 40 years or less to reduce the likelihood of osteoarthritic changes in the patellofemoral joint. Subjects were excluded if they had (i) previous knee surgery, or a knee condition other than PFP; (ii) abnormal sensation across the anterior portion of the knee; (iii) an allergy to adhesive taping; (iv) were highly trained; (v) performed high level exercise 6 h prior to testing; (vi) pain or injury present in adjacent joints including the hip, ankle and foot; (vii) contraindications to invasive procedures such as coagulopathies; or (viii) had received recent intervention for PFP. The subjects did not have pain at rest, and did not have pain during a gentle isometric contraction at 30° knee flexion. This has important

implications on the recordings, as it has been found that motor unit firing frequency can be affected by the presence of pain [19,37]. The study was approved by the institutional research ethics committee.

### Electromyographic activity

Electromyographic activity of individual motor units in VMO was recorded with a monopolar ( $n = 2$ ) (TECA, Oxford Metrics, UK, 50 mm  $\times$  26 gauge) or concentric needle electrode ( $n = 6$ ) (TECA, Oxford Metrics, UK, 50 mm  $\times$  26 gauge) inserted into the muscle 20 mm proximal to its distal border in the middle of the muscle belly (Fig. 1a). When using a monopolar needle electrode a surface electrode (20 mm Ag/AgCl disc, Grass Telefactor, USA) was placed 10 mm medial to its insertion point as a reference. Pairs of surface electrodes (20 mm Ag/AgCl disc, Grass Telefactor, USA) were placed in standardized positions based on previous studies [17], over the muscle bellies of VL and VMO with an interelectrode distance of 20 mm (Fig. 1a.). The electrodes for VMO were positioned 4 cm superior and 3 cm medial to the superomedial border of the patella, and oriented 55° to the vertical. For VL, the electrodes were placed 10 cm superior and 6–8 cm lateral to the superior border of the patella, and oriented 15° to the vertical. A ground electrode was placed over the tibia. Prior to application of the electrodes, the skin was prepared with abrasive gel and wiped with alcohol to minimise electrical impedance.

In order to avoid recording from the same motor units in different trials, the morphology of the motor unit was identified from averages of the VMO surface EMG recordings, triggered from the single motor unit action potentials in the monopolar needle recording. The averages were observed both during the experiment and offline following completion of the experiment.

EMG data were pre-amplified 1000 times, band-pass filtered between 20 Hz and 2 kHz (Neurolog, Digitimer UK) and sampled at 5 kHz. Data were sampled using a Power 1401 (Cambridge Electronic Design, UK) and Spike2 (Version 4.10) software (CED, Cambridge, UK).

### Procedure

As it was critical to control the force level and intramuscular electrode position across trials it was necessary to position subjects in non-weight bearing. Subjects were seated on an adjustable plinth with the hip in neutral rotation and flexed to 90°, and the knee flexed 30° from extension over a solid frame (Fig. 1a). The thigh was stabilized with a Velcro strap, and the subject's foot resting in a neutral position

of dorsiflexion/plantar flexion on a wooden footplate supported in a fixed frame. It is important that this position is standardized for all subjects, as different hip and knee joint angles, and type of contraction, can influence the relative activity of the vasti muscles [23,41]. The footplate was attached to a strap linked in series with a strain gauge (Validyne, USA) to provide feedback of knee extension force (Fig. 1b). The subject only exerted sufficient force to enable recording of the activity of a single, or small number of motor units. Typically, the force generated was less than 5% maximum voluntary contraction. Although the absolute force level was not critical, it was important that subjects maintained a constant force level between trials. A cross of rigid tape (Leukoplast, Biersdorf, NSW) was placed over the patella to allow the application of force to the skin. Hypoallergenic tape (Fixomull stretch, BSN medical, Hamburg) was also used to aid fixation of the tape (Fig. 1b). The force was applied in the three directions of medial, lateral and superior, via a strain gauge to ensure constant force across all trials.

The needle electrode was inserted into the muscle belly of VMO and adjusted within the muscle to obtain a clear recording from a single motor unit. Optimal placement of the electrode was determined from motor unit morphology displayed on an oscilloscope. During each trial, subjects were requested to maintain a gentle knee extension effort at constant force, assisted by visual feedback of force on a computer monitor. The experimenter monitoring single motor unit firing had continuous auditory feedback of motor unit activity via headphones to ensure that the firing of the reference unit was maintained. This individual received no feedback about the application of stretch to the skin.

We aimed to record 5 motor units from each subject, with recordings made during medial, superior and lateral skin stretch for each motor unit. This was achieved for seven of eight subjects with 4 motor unit recordings for the other subject. For each trial, a constant knee extension force was maintained while stretch was applied to the skin in either a medial, lateral or superior direction. The direction of tape pull was randomized for all trials. A metronome was used to regulate the duration of tension applied to the skin with 3 s ramp up, 3 s hold, 3 s ramp down and 3 s with no stretch (Fig. 1c). The level of force applied to the tape was determined from pilot trials, with a maximum force (4 N) which was less than that required to produce movement of the patella or the lower limb but sufficient to stretch the skin.

### Data analysis

Sorting of motor unit recordings was conducted using a Spike discriminator (BAK Electronics) which identifies individual motor units through analysis of the slope of the rise phase of an action potential.

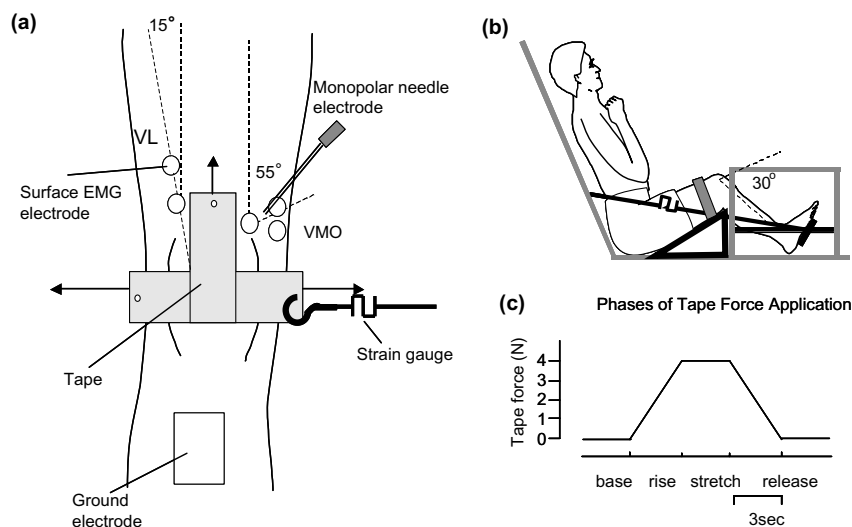


Fig. 1. Experimental set-up (a) Surface and needle EMG electrode placement over VMO and VL with application of tape to the skin over the patella. (b) Subject Position. Subjects were seated with the knee supported in 30° flexion over a stable frame. (c) Phases of skin stretch via tape over the patella.

To distinguish between motor units, triggers were created based on high and low phases of the action potential. On completion of the experiment the triggers were checked offline and errors were corrected to ensure accuracy of action potential discrimination. This is necessary as motor unit action potential morphology (particularly amplitude) may change during long recordings. For each motor unit the instantaneous firing rate was calculated for the middle 1 s during each phase of tape tensioning (baseline, rise, stretch and release) and a comparison was made of the mean firing rate between the different phases. The root mean square (RMS) amplitude of VMO and VL surface recordings was also calculated for 1 s during each phase (baseline, rise, stretch and release) and normalized to the amplitude recorded during the baseline control phase in which the knee was extended but without skin stretch. The phases of stretch were investigated to evaluate whether the responses to stretch differed between the dynamic and static phases of the stretch.

#### Statistical analysis

The software program Statistica (Version 5, Statsoft Inc., USA) was used to conduct statistical analysis of the data. A two factor repeated measures analysis of variance (phase  $\times$  direction) was used to compare VMO single motor unit firing rate and RMS EMG between phases of stretch (baseline, rise, stretch and release) and the direction of tape tension (medial, lateral and superior). Post-hoc testing was conducted using Duncan's Multiple Range Test to identify specific differences in the data. Alpha level was set at 0.05.

## Results

### EMG amplitude

When tension was applied to the skin over the patella in people with PFP, there was a change in VMO surface EMG amplitude which varied significantly between the directions of skin stretch ( $p < 0.001$ ) (Fig. 2a). With application of a lateral stretch to the skin, which tensioned the skin over VMO, there was a 9% ( $\pm 0.045$ ) increase in VMO EMG amplitude which was greater than that identified with medial and superior stretch ( $p = < 0.001$ ). The amplitude of VMO EMG also differed between the phases of stretch with increased amplitude on the stretch and release phases compared to the rise phase ( $p = 0.03$ ) (Fig. 3). There was a variable response between subjects to phase and direction

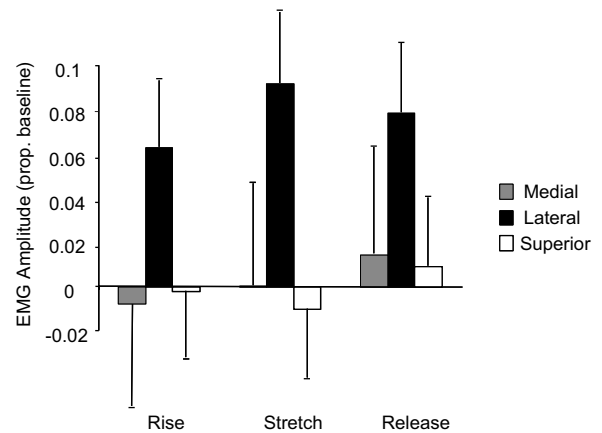


Fig. 3. Mean VMO surface EMG amplitude with different phases of skin stretch which indicates greater amplitude with stretch and release phases. Note also the increase in amplitude across all phases with lateral stretch. Standard deviations are shown.

( $p = 0.0039$ ). Subject 5, in particular, responded to lateral stretch with a larger increase in amplitude than the other subjects ( $p = 0.02$ ).

In contrast to VMO, VL EMG activity did not differ between directions of tape pull and phase of skin stretch ( $p = 0.2, 0.3$ ) (Fig. 2b). However, there was significant variability in amplitude between subjects. As with VMO, subject 5 had a larger response to skin stretch than the other seven subjects ( $p = 0.006$ ).

Consistent with VMO surface recording, analysis of RMS EMG amplitude of the intramuscular recording of VMO indicated a significant increase in amplitude with lateral stretch of the skin which was greater than that with either medial or superior stretch ( $p = 0.02$ ). This change was present despite slight alterations in motor unit action potential size, which occurred as a result of minor movements of the needle electrode within the muscle. However, there was no difference in amplitude of VMO intramuscular EMG when compared between the three phases of skin stretch ( $p = 0.59$ ).

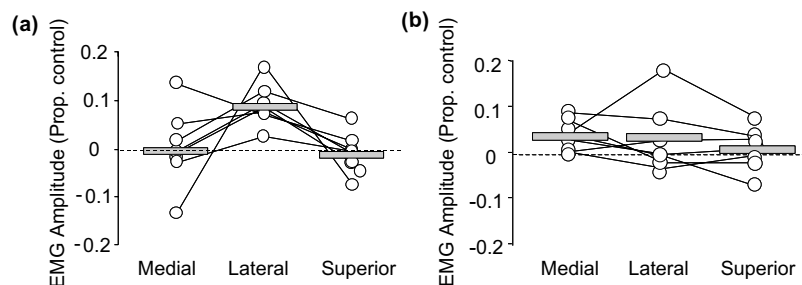


Fig. 2. (a) Individual (circles) and group (grey bar) mean VMO surface EMG amplitude with different directions of skin stretch. EMG data are shown relative to the control amplitude recorded during knee extension without skin stretch. Note consistent increase in amplitude with lateral stretch compared to medial and superior stretch. (b) The VL surface EMG amplitude for individual subjects (circles) and group (grey bar) across different directions of stretch. Note that VL amplitude did not change from baseline for all directions of skin stretch.

### VMO motor unit firing rate

With the application of stretch to the skin over the patella in people with PFP, a high proportion of motor units altered their firing rate. The response of individual motor units was not consistent for each direction or phase of skin stretch. Analysis of mean firing rate averaged across all motor units demonstrated no net difference for the pool of motor units tested. There was no significant difference between the means when compared across the directions of pull ( $p = 0.5$ ) and the phase of skin stretch ( $p = 0.1$ ) (Fig. 4), however when the means of individual motor units were analysed the data showed that 52.5%, 67.5% and 60.5% of motor units increased firing rate with medial, lateral and superior stretch of the skin, respectively. Raw data for an individual subject is displayed in Fig. 5. The motor unit presented has a

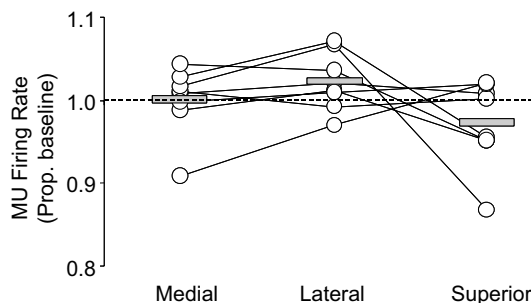


Fig. 4. Mean firing rate for VMO motor units, averaged across all motor units for each subject (circles) and the group (grey bar), for different directions of skin stretch.

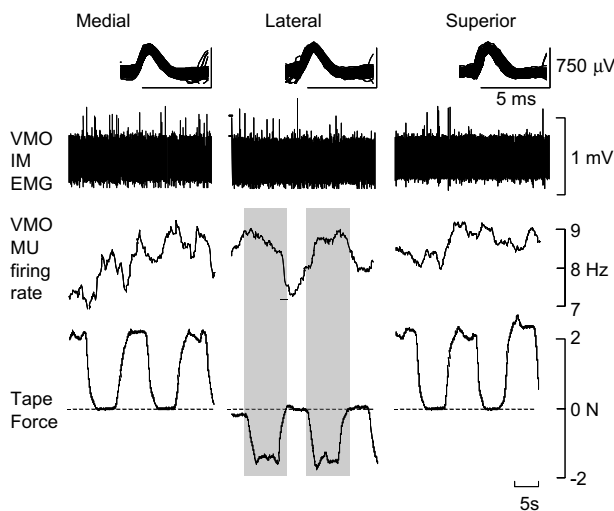


Fig. 5. Raw data from an individual subject illustrating the response of a single motor unit to stretch of the skin in the three directions—medial, lateral and superior. The superimposed motor unit action potentials (top) confirm that the same motor unit was recorded in each trial. This motor unit increased firing rate with stretch specifically in the lateral direction.

clear increase in firing rate with lateral stretch of the skin, but not with medial or superior stretch. Of the motor units in which firing rate increased, the mean increase for medial, lateral and superior stretch was 6% (0.3–14%), 6% (0.02–19%) and 4% (0–15%), respectively.

Some motor units responded to skin stretch with decreased firing rate. Of the 40 motor units from which data was collected, 47.5%, 32.5% and 39.5% decreased their firing rate with medial, lateral and superior skin stretch. This reduction in firing rate was 6% (1–37%), 6% (1–22%) and 8% (0–30%) for medial, lateral and superior skin stretch.

### Discussion

The present study shows that stretch of the skin over the patella, which stimulates cutaneous afferent receptors, leads to changes in VMO amplitude and motor unit firing rate. Application of a lateral stretch, which tensions the skin over VMO, resulted in increased VMO surface EMG amplitude, with no concurrent increase in VL EMG activity. Although there was no net increase in firing rate across all motor units, individual analysis suggests that during lateral stretch, a greater proportion of motor units increased firing rate than decreased. Therefore, although cutaneous stimulation with stretch in a lateral direction did increase firing rate in the majority of motor units, the response was not consistent across the motor unit pool. The findings of the study support the hypothesis that stimulation of cutaneous afferents and the subsequent effect on VMO activity may play a role in the clinical effect of patella taping.

The effect of skin stretch on vasti muscle activity demonstrated in this study concurs with previous research that has investigated the relationship between cutaneous afferents and motor unit activity. McNulty et al. [28] demonstrated that activity of hand muscles is coupled to firing of single cutaneous afferents in the hand. Similarly, stimulation of cutaneous afferents in the foot in cats has been shown to alter motor unit excitability [20]. Furthermore, stimulation of cutaneous afferents in the hand can alter the order of recruitment of motor units such that high threshold motor units are among the first to be recruited [15]. There is also evidence from several studies to suggest that cutaneous stimulation contributes to the perception of joint position and movement [7,12,13], and this factor may have some effect on the degree of muscle activity.

Kandel et al. [21] report that cutaneous stimulation can lead to reflex contraction of the muscle underlying the stimulated skin. Furthermore, the specific type of stimulus can influence the muscle response. Hargbath et al. [20] demonstrated that cutaneous stimulation of the foot can contribute to excitation of specific motor units, while inhibition of motor units in the corresponding

antagonist muscle occurs. It was also reported that cutaneous stimulation can lower the threshold of recruitment of motor units in the underlying muscle, such that motor units are more easily excited [21]. The specificity of increased VMO activity to lateral stretch of skin over the patella, is consistent with the specificity to different types of stretch identified in these previous studies.

It is argued that individuals with PFP demonstrate abnormal lateral tracking of the patella. Movement of the patella is controlled by both passive and dynamic structures surrounding the knee, and it has been suggested that an imbalance in the activity of the medial and lateral vasti muscles may contribute to altered patella tracking and consequently lead to pain [40]. Several studies provide evidence to suggest that while VMO and VL onset occurs simultaneously in asymptomatic subjects, there is a delay in VMO onset relative to VL in subjects with PFP during the performance of functional tasks [10,11]. Other studies have failed to find a difference in timing in patients with PFP. However, it is difficult to compare between studies, due to differences in the tasks performed, measurement techniques and methods of analysis. For instance, studies measuring reflex latencies to a tap to the patella tendon only provide information on the latency of the stretch reflex [22] and do not provide information on how the activity of these muscles is controlled during functional activities. Other factors that influence the results include methods for detection of EMG onset (using computer algorithms or visual detection) and whether the onset of vasti EMG activity is expressed relative to each other or relative to mechanical events [33,36].

The present data, which indicate VMO activity can be increased differentially by cutaneous stimulation of the skin over the patella, suggest that this may provide a mechanism to improve control of the medial and lateral muscles. Furthermore, if it is accepted that individuals with PFP have deficits in vasti muscle control it is possible that this population of individuals should respond differently to skin stretch over the patella compared with healthy individuals in whom vasti muscle activity is optimal. When data from the present study are considered relative to data from a recent study investigating the effect of stretch on skin over the patella in healthy individuals, using an identical experimental paradigm, the results indicate that subjects with PFP showed an increase in VMO amplitude in response to skin stretch in a lateral direction almost one third greater than that identified in healthy subjects (6%) (Gerlach et al., unpublished observations). The greater response seen in PFP subjects is consistent with the change in timing of vasti muscle activity which was found in individuals with PFP, but not painfree individuals, in previous research [10,11].

The increased amplitude of VMO activity identified in the present study supports previous findings which

show a change in vasti muscle activity with patella taping [6,31]. In contrast, Ng et al. [30] reported a decrease in VMO/VL ratio with patella taping. However, that study involved a high loading task which may influence the results. Several other studies have found no change in vasti activity with patella taping during stair climbing tasks or VMO retraining exercises [5,8,35]. These tasks are associated with large inter-trial variability which is likely to have influenced the ability to identify a difference. The technique used in the present study was very sensitive, due to the careful control of the task and knee extension force, and demonstrated a small but consistent effect on vasti muscle activity.

The present study also showed a greater tendency for motor unit firing rate in VMO to increase rather than decrease with lateral stretch of the skin over the patella. There are several possible explanations for the variable response of motor units to skin stretch. For instance, there may be some degree of task specificity in VMO motor units related to control of the patella. Task specificity of motor units has been reported in other muscles such as transversus abdominis and obliquus internus in relation to postural and respiratory functions [34]. Thus the variable response of VMO motor units to stretch may reflect the functional difference in VMO motor units. In our study, subjects performed low force contractions which are likely to recruit low threshold motor units. There may be differences between motor units with varying recruitment thresholds, such that different levels of cutaneous input are required to stimulate various motor units. This factor was not considered in the present study, however it may contribute to the individual variation in motor unit activity seen in the results.

Although therapeutic patella taping involves application of tape to correct components of patella orientation, the current study involved application of a cross of rigid tape to the skin directly over the patella. Clinically, tape is applied first to the patella and then tensioned medially with fixation over the medial knee and VMO. This technique provides some degree of medial stretch over the patella, compression of the skin over the medial knee and lateral stretch over the medial joint, including some lateral stretch over VMO. In this study the tape was tensioned at a standardized force of 4 N in the three different directions to apply stretch to the skin. When the tape was pulled in a lateral direction, the skin over VMO and the medial knee was stretched, and when pulled in a medial direction the tape stretched the skin over the patella. Thus the technique used is not an ideal model of clinical patella taping. However clinical patella taping does involve both components of stretch, and it appears that the lateral stretch over the muscle has the most significant effect on muscle activity. The tape was also pulled in a superior direction as a control, as this component is not incorporated into therapeutic patella taping. This direction of stretch induced

no change in VMO activity, although 60% of motor units had a small increase in firing rate.

Other techniques have also been shown to alter vasti muscle activity. Application of tape transversely over VL, with the aim of reducing VL activity relative to VMO, has been shown to have this effect in asymptomatic subjects [39]. Thus, the direction of tape application has specific effects on muscle activity. The direction of tape application in the current study had no effect on VL activity, despite altering VMO activity, which may be related to the anatomical orientation of the muscles and their respective roles in patellar control. The majority of muscle fibres in VL are vertically orientated to the patella and have a significant role in extension of the knee, while producing only a small lateral glide of the patella. In our study the tape was directed horizontally with minimal likely influence on the muscle which lies further proximal. In comparison, the fibres of VMO are more horizontally oriented and are responsible for medial control of the patella [25]. Thus VMO creates a more superomedial force on the patellofemoral joint, which is important in the control of the patella during knee movements [26], and in particular in individuals with PFP. Unlike VL, the application of stretch to the skin over the patella was more closely related to muscle fibre direction and action of VMO.

The present study demonstrates that stretch of the skin over VMO via tape, can increase VMO EMG activity, and this effect appears greater in subjects with PFP than that reported for asymptomatic subjects. This suggests that stimulation of cutaneous afferents may contribute to the mechanism by which patella taping produces a positive clinical effect in this population. The principle could be considered in a variety of taping techniques for other anatomical areas to explain the clinical effect identified by therapists.

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## References

- [1] Barrett DS, Cobb AG, Bentley G. Joint proprioception in normal, osteoarthritic and replaced knees. *J Bone Joint Surg Br* 1991; 73:53–6.
- [2] Bockrath K, Wooden C, Worrell T, Ingersoll CD, Farr J. Effects of patella taping on patella position and perceived pain. *Med Sci Sports Exerc* 1993;25:989–92.
- [3] Brukner P, Khan K. *Clinical sports medicine*. Sydney: McGraw-Hill; 2000.
- [4] Callaghan MJ, Selfe J, Bagley PJ, Oldham JA. The effects of patellar taping on knee joint proprioception. *J Athl Train* 2002; 37:19–24.
- [5] Cerny K. Vastus medialis oblique/vastus lateralis muscle activity ratios for selected exercises in persons with and without patellofemoral pain syndrome. *Phys Ther* 1995;75:672–83.
- [6] Christou EA, Carlton LG. The effect of knee taping on the EMG activity of the vastus medialis oblique and vastus lateralis muscles. *Med Sci Sports Exerc* 1997;29.
- [7] Collins DF, Refshauge KM, Gandevia SC. Sensory integration in the perception of movements at the human metacarpophalangeal joint. *J Physiol* 2000;529(Pt 2):505–15.
- [8] Cowan SM, Bennell K, Hodges P, Crossley K. Does patellar taping change the magnitude of EMG activity of the vasti? Submitted.
- [9] Cowan SM, Bennell KL, Hodges PW. Therapeutic patellar taping changes the timing of vasti muscle activation in people with patellofemoral pain syndrome. *Clin J Sport Med* 2002;12:339–47.
- [10] Cowan SM, Bennell KL, Hodges PW, Crossley KM, McConnell J. Delayed onset of electromyographic activity of vastus medialis obliquus relative to vastus lateralis in subjects with patellofemoral pain syndrome. *Arch Phys Med Rehabil* 2001;82:183–9.
- [11] Cowan SM, Hodges PW, Bennell KL, Crossley KM. Altered vastii recruitment when people with patellofemoral pain syndrome complete a postural task. *Arch Phys Med Rehabil* 2002;83:989–95.
- [12] Edin B. Cutaneous afferents provide information about knee joint movements in humans. *J Physiol* 2001;531:289–97.
- [13] Edin BB, Abbs JH. Finger movement responses of cutaneous mechanoreceptors in the dorsal skin of the human hand. *J Neurophysiol* 1991;65:657–70.
- [14] Fairbank JC, Pynsent PB, van Poortvliet JA, Phillips H. Mechanical factors in the incidence of knee pain in adolescents and young adults. *J Bone Joint Surg Br* 1984;66:685–93.
- [15] Garnett R, Stephens JA. Changes in the recruitment threshold of motor units produced by cutaneous stimulation in man. *J Physiol* 1981;311:463–73.
- [16] Gerrard B. The patello-femoral pain syndrome: A clinical trial of the McConnell programme. *Aust J Physiother* 1989;35:71–9.
- [17] Gilleard W, McConnell J, Parsons D. The effect of patellar taping on the onset of vastus medialis obliquus and vastus lateralis muscle activity in persons with patellofemoral pain. *Phys Ther* 1998;78:25–32.
- [18] Grabiner MD, Koh TJ, Draganich LF. Neuromechanics of the patellofemoral joint. *Med Sci Sports Exerc* 1994;26:10–21.
- [19] Graven-Nielsen T, Svensson P, Arendt-Nielsen L. Effects of experimental muscle pain on muscle activity and co-ordination during static and dynamic motor function. *Electroencephalogr Clin Neurophysiol* 1997;105:156–64.
- [20] Hargbath KE. Excitatory and inhibitory skin areas for flexor and extensor motoneurons. *Acta Physiol Scand* 1952;26:1–58.
- [21] Kandel ER, Schwartz JH, Jessell TM. *Touch*. In: Kandel ER, Schwartz JH, Jessell TM, editors. *Principles of Neural Science*. New York: McGraw-Hill; 1991.
- [22] Karst GM, Willett GM. Onset timing of electromyographic activity in the vastus medialis oblique and vastus lateralis muscles in subjects with and without patellofemoral pain syndrome. *Phys Ther* 1995;75:813–23.
- [23] Lam PL, Ng GY. Activation of the quadriceps muscle during semisquatting with different hip and knee positions in patients with anterior knee pain. *Am J Phys Med Rehabil* 2001;80:804–8.
- [24] Lephart SM, Pincivero DM, Rozzi SL. Proprioception of the ankle and knee. *Sports Med* 1998;25:149–55.
- [25] Lieb FJ, Perry J. Quadriceps function. An anatomical and mechanical study using amputated limbs. *J Bone Joint Surg Am* 1968;50:1535–48.
- [26] Lin F, Makhosous M, Koh JL. In vivo patellar tracking in patellar malaligned knees. In: *IVth World Congress of Biomechanics*. Calgary, Canada, 2002.
- [27] McConnell J. The management of chondromalacia patellae: a long term solution. *Aust J Physiother* 1986;32:215–23.

- [28] McNulty PA, Turker KS, Macefield VG. Evidence for strong synaptic coupling between single tactile afferents and motoneurons supplying the human hand. *J Physiol* 1999;518(Pt 3):883–93.
- [29] Neptune RR, Wright IC, van den Bogert AJ. The influence of orthotic devices and vastus medialis strength and timing on patellofemoral loads during running. *Clin Biomech (Bristol, Avon)* 2000;15:611–8.
- [30] Ng GY, Cheng JM. The effects of patellar taping on pain and neuromuscular performance in subjects with patellofemoral pain syndrome. *Clin Rehabil* 2002;16:821–7.
- [31] Nicholas RM, Bullock-Saxton JE, Reed JC. Patellofemoral pain in the sportsperson: which rehabilitation exercises are best and is patella taping of benefit?. *Br J Sports Med* 1996;30:369.
- [32] Perla R, Frank C, Fick G. The effect of elastic bandages on human knee proprioception in the uninjured population. *Am J Sports Med* 1995;23:251–5.
- [33] Powers CM. Patellar kinematics, part I: the influence of vastus muscle activity in subjects with and without patellofemoral pain. *Phys Ther* 2000;80:956–64.
- [34] Puckree T, Cerny F, Bishop B. Abdominal motor unit activity during respiratory and nonrespiratory tasks. *J Appl Physiol* 1998;84:1707–15.
- [35] Salsich GB, Brechter JH, Farwell D, Powers CM. The effects of patellar taping on knee kinetics, kinematics, and vastus lateralis muscle activity during stair ambulation in individuals with patellofemoral pain. *J Orthop Sports Phys Ther* 2002;32:3–10.
- [36] Sheehy P, Burdett RG, Irrgang JJ, VanSwearingen J. An electromyographic study of vastus medialis oblique and vastus lateralis activity while ascending and descending steps. *J Orthop Sports Phys Ther* 1998;27:423–9.
- [37] Sohn MK, Graven-Nielsen T, Arendt-Nielsen L, Svensson P. Inhibition of motor unit firing during experimental muscle pain in humans. *Muscle Nerve* 2000;23:1219–26.
- [38] Somes S, Worrell TW, Corey B, Ingersoll CD. Effects of patella taping on patellar position in the open and closed kinetic chain: a preliminary study. *J Sports Rehabil* 1997;6:299–308.
- [39] Tobin S, Robinson GA. The effect of McConnell's vastus lateralis inhibition taping technique on vastus lateralis and vastus medialis obliquus activity. *Physiotherapy* 2000;86:173–83.
- [40] Voight ML, Wieder DL. Comparative reflex response times of vastus medialis obliquus and vastus lateralis in normal subjects and subjects with extensor mechanism dysfunction. An electromyographic study. *Am J Sports Med* 1991;19:131–7.
- [41] Wilk KE, Escamilla RF, Fleisig GS, Barrentine SW, Andrews JR, Boyd ML. A comparison of tibiofemoral joint forces and electromyographic activity during open and closed kinetic chain exercises. *Am J Sports Med* 1996;24:518–27.