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An electromyographical study to investigate the effects of patellar taping on the vastus medialis/vastus lateralis ratio in asymptomatic participants

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It is commonly theorised that patellofemoral pain syndrome (PFPS) is caused by maltracking due to vastus medialis (VM) weakness relative to the vastus lateralis (VL). Despite this being a controversial theory, patellar taping is a commonly used technique that purports to correct this muscle imbalance by increasing the VM/VL ratio. The effects of different forms of taping on vasti muscle activity are still not known. The objective of this study was to investigate the effects of three different types of patellar taping on the VM/VL ratio in asymptomatic university students. Each participant performed a set of four single–legged squats under four separate taping conditions: A) medial, B) lateral, C) neutral, and D) no-tape. The condition sequence was randomised. The main outcome measure was the normalised VM/VL ratio, assessed by using surface electromyography.

Secondary outcome measures were the normalised EMG activity of the VM and the VL. A convenience sample of 24 (17 females) students (22±10 years, M±SD) completed this study. The lateral taping condition produced small but significantly greater VM/VL ratios than the medial ($p=0.007$) and neutral ($p=0.007$) but not the no-tape ($p=0.123$) condition. There were no significant differences between the medial, neutral, and no-tape conditions. These results question whether patellar taping can impart a clinically significant effect on the VM/VL ratio. The results of this study cannot be directly extrapolated to a patient population, and further research in the PFPS population is required before clinical recommendations can be made.

Introduction

In Britain, patellofemoral pain syndrome (PFPS) accounts for over 5% of all injuries seen in an athletic population and 25% of all knee injuries (Devereaux and Lachmann, 1984). The symptoms usually include the insidious onset of anterior knee pain, which is exacerbated by activities such as ascending and descending stairs, squatting, kneeling, and prolonged sitting (Doucette and Goble, 1992). There is a lack of consensus about its pathophysiology. The most widely accepted hypothesis is that patellar maltracking results in abnormal joint stress and subsequent articular cartilage ware (Powers, 1998).

It is commonly theorised that maltracking is a result of vastus medialis (VM) weakening relative to the vastus lateralis (VL), resulting in lateral tracking of the patella (McConnell, 1986). The evidence to support this theory is

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conflicting. Some electromyography (EMG) studies have identified a decreased VM/VL ratio in PFPS patients (Miller, Sedory, and Croce, 1997; Mariani and Caruso, 1979; Boucher, King, Lefebvre, and Pepitt, 1992), whereas others have not (Powers, Landel, and Perry, 1996; Sheehy, Burdett, Irrgang, and VanSwearingen 1998). The reason for the confliction within the literature is probably related to methodological differences. Regardless of whether such an imbalance exists, many therapists use patellar taping in an attempt to correct this imbalance by increasing the activity of the VM relative to the VL (Brody and Thein, 1998). The purpose of this article is to investigate if this commonly used technique does what it purports to do—increase the VM/VL ratio.

In 1986, Jenny McConnell devised a form of patellar taping, "McConnell taping," which purports to medially realign the patella, improving tracking, eliminating abnormal forces, thus decreasing pain (McConnell, 1986). McConnell also found that a medial glide increased the VM/VL ratio and suggested that medial glide taping could in the long-term rectify the VM/VL imbalance in PFPS by selectively strengthening the VM during exercise (McConnell, 1986).

In contrast, later studies have found patellar taping to have no effect on the VM/VL ratio in PFPS (Cerny, 1995). Indeed, recent evidence suggests that medial taping may decrease the VM/VL ratio (Ng and Cheng, 2002). It was proposed that the latter occurred because the tape medially stabilised the patella; thus, there was less need for VM activity. This may defeat the purpose of McConnell's exercise therapy, which in part attempts to increase the VM/VL ratio (Brody and Thein, 1998).

On the basis of the findings of Ng and Cheng (2002), it is plausible that laterally gliding the patella could increase the VM activity relative to VL, thus increasing the VM/VL ratio. Such an alteration in vasti activity would facilitate rehabilitation by increasing the VM/VL ratio, yet the pain-relieving effects should be similar if not superior to that seen for a medial glide (Wilson, Carter, and Thomas, 2003).

Although the existence of vasti imbalance in PFPS remains controversial, currently many therapists use patellar taping in the treatment of PFPS because it is purported that taping can increase the VM/VL ratio. There is still much debate within the literature regarding the effects of taping on vasti activity. The effect of lateral patellar gliding on vasti muscle activity has not been investigated. If a lateral glide was found to be superior to a medial glide for increasing the VM/VL ratio, one may need to reevaluate the taping treatment techniques used in PFPS. In addition, if taping were to have little or no effect on vasti activity, its use to correct muscle imbalance in PFPS patients should also be questioned. Thus, the aim of this study was to investigate the effect of a medial, lateral, and a neutral patellar glide on vasti activity compared with a no-taping control condition.

Methodology

Participants

A convenience sample of 25 college students was recruited into this study. The exclusion criteria were a history of injury involving the knee, prior knee surgery, recent (within 1 year) or current history of lower limb pain requiring consultation with a health professional, history of cardiovascular disease or hypertension. Signed, informed consent was obtained before participating. Ethical approval for the study was given by Queen Margaret University College Edinburgh.

Testing procedure

Each participant was seen on two occasions. On the first occasion, they performed two maximal voluntary contractions (MVCs) and three submaximal sets at 50% of the MVC. These tests ensured that on the day of testing true MVC and 50% MVC tests were performed and provided practice using the biofeedback equipment used in the 50% MVC test. No EMG data were recorded on the first day. Participants' height and weight were also recorded. On the second occasion, each participant began with two MVCs followed by four submaximal 50% MVCs. Each submaximal MVC was held for 10 seconds, and all participants achieved a steady-state contraction within 3 seconds. The main study data were then recorded. Four squats for each of the four taping conditions were performed. Each squat was performed to

30° of knee flexion on the dominant leg only, while barefoot. The degree of flexion was assessed by using a universal goniometer. The order of the four conditions was randomised for each subject by using a balanced Latin square design.

Normalisation procedure

Each participant sat with the hips and knees in 90° of flexion. A strain gauge myometer (MIE Medical Research®) was attached above the ankle of the dominant leg, and the moment arm of the myometer with respect to the knee was measured. A belt was used to prevent the hips from lifting off the chair during the exercise. Participants performed two maximal voluntary contractions with a rest of 2 minutes between them. Four submaximal contractions were then performed at 50% of the torque produced during the greater of the two MVCs. This was achieved by using visual biofeedback (MIE Medical Research®), in which the participant had to hold a bar chart steady on a computer screen. The bar was set to represent a torque equivalent to 50% of MVC. The mean EMG activity recorded for the VM and VL during the 50% MVC was used to normalise the data in accordance with the method of Laprade, Culham, and Brouwer, 1998.

Patellar taping conditions

The four taping conditions used were a A) lateral glide, B) medial glide, C) neutral glide, and D) no-tape/glide. For the lateral, medial, and neutral glides, an adhesive undertape (BSN Medical, Leukolastic®) was placed over the patella and completely encircled the knee joint. The rigid tape (BSN Medical, Leukotape®) was then attached to the under tape to perform the glides. No undertape was used for the "no-tape" condition.

The application of the tape and taping forces were applied in a standardised manner. For the lateral glide taping, the participant lay in half sitting (i.e., hips at 90° and the knee straight). The knee musculature was relaxed. The physiotherapist fastened the rigid tape approximately 1 cm medial to the patella and then over the top of the patella. The therapist then applied lateral pressure to the medial border of the patella with his thumb while pulling the patella laterally with the tape. Once at the end range of motion, the rigid tape was fastened to the undertape on the lateral side of the knee joint, and the patella was fixed in that position. This procedure was repeated with two more strips of tape until the therapist was confident that end-range lateral displacement was achieved. The medial glide was performed in the same manner but in the opposite direction. For the neutral glide, the rigid tape was applied to the top of the patella and then pulled down either side so that the patella was not pulled in either direction but a downward pressure was created. Finally for the no-tape/no-glide condition, no tape of any form was applied to the patellofemoral joint.

Evaluation

EMG activity of the VL and the VM was recorded by using bipolar surface electrodes. Dry electrodes were used (SX230, Biometrics®), which possess a high input impedance (>10,000,000 M Ohms), thus little or no skin preparation was required. The electrode positioning corresponded to the procedure used by Cowan et al. (2001). Briefly, the electrode for the VM was placed over the muscle belly of the oblique portion of the VM commonly known as the Vastus Medialis Oblique (VMO), approximately 4 cm superior and 3 cm medial to the superomedial patellar border, with an orientation of 55° to the femur. Because it is doubtful that the electrodes were purely picking up VMO activity in isolation of the longus part of the vastus medialis, it will be stated that the electrical activity of the vastus medialis was measured. A VL electrode was placed over the muscle belly approximately 10 cm superior and 6–8 cm lateral to the superior border of the patella with an orientation of 15° to the femur.

The EMG signal was preamplified, with a gain of 1,000, and band pass filtered between 20 and 450 Hz. A common-mode-rejection-ratio (CMRR) of 110 DB was used to optimise noise removal. The signal was 12-bit A-D converted by using a Datalink A-D converter (Biometrics®), with a sampling frequency of 1,000 Hz. Once the raw signal was collected and saved, it was then processed by using a root-mean-squared (RMS) technique with a time constant of 500 ms. An RMS time constant of this length was used because it has been shown to produce superior within-subject reproducibility compared with shorter time lengths for isometric contractions (Bamman, Ingram, Caruso, and Greenisen, 1997; St-Amant, Rancourt, and Clancy, 1998).

Mean RMS amplitude for 2 seconds of each contraction was used to assess muscle activity. The period analysed was between the 2nd and 4th seconds of each contraction, except for the 50% MVC where the data was taken for three seconds between the 3rd and the 6th second. The latter time period was chosen because it took until the 3rd second for a steady torque to be produced during this contraction type.

To detect any changes in muscle activity brought about by patellar taping, the primary outcome measure used was the normalised EMG VM/VL ratio. The secondary outcome measures were the normalised EMG VM and VL activity.

Statistical analysis

Statistical normality of the data was assessed by using a one-sample Shapiro-Wilks test. Normally distributed group data were assessed by using a one-way repeated measure ANOVA. An alpha level of 0.05 was deemed statistically significant. Where a significant difference was indicated by the ANOVA, a series of paired t-tests with bonferonni correction was used to identify where the significance existed. Non-normally distributed data were assessed by using Friedman's test. Where a significant difference was indicated by the Friedman's test, a series of Wilcoxin Signed ranks tests with bonferonni correction was used to identify where the significance occurred. The bonferonni correction resulted in a p-value of $p \leq 0.0083$ for statistical difference to be established.

Table 1. Participant information.

Parameter	Mean ± SD
Gender	17 F and 7 M
Age (yr)	24 ± 2.7
Height (m)	1.69 ± 0.7
Weight (kg)	68.8 ± 10.1
BMI (kg/m^2)	24.1 ± 2.8

All data are given as means ± 1 SD.

Results

Twenty-five college students were recruited. One participant failed to complete the experiment, Because of nauseous feelings when her patella was moved. The information for the remaining 24 participants is provided in Table 1. There were no significant differences in EMG muscle activity between participants of different genders and different patellar mobility. Thus, the data for all 24 participants were pooled.

Table 2 shows the EMG RMS amplitude data for the VM, VL, and VM/VL. Table 3 shows that the VL and VM data were normally distributed. Thus, these sets of data were analysed by using parametric statistics (repeated-measures ANOVA). The VM/VL ratio data were not normally distributed; thus, this data set was analysed by using nonparametric statistics (Friedman's test). A Friedman's test revealed that taping had a significant effect on VM/VL activity (chi-square = 9.65; df = 3; $p = 0.022$) (Figure 1).

A series of Wilcoxin signed ranks tests revealed that the VM/VL ratio for the lateral taping condition was significantly greater than

Table 2. EMG activity for the different experimental conditions.

	Lateral	Medial	Neutral	No tape
VMO	0.604 (0.196)	0.584 (0.189)	0.601 (0.180)	0.599 (0.167)
VL	0.461 (0.135)	0.472 (0.143)	0.484 (0.143)	0.480 (0.143)
VMO/VL	1.375 (0.506)	1.314 (0.549)	1.322 (0.532)	1.317 (0.440)

The EMG activity for the VMO and VL during the different taping conditions normalised to 50%MVC. Data are provided as means (1 SD).

Table 3. Shapiro-Wilks test of normality.

	Shapiro-Wilks test		
Taping condition	Statistic	df	Significance
VMO/VL			
Lateral	0.877	24	0.007
Medial	0.814	24	0.001
Neutral	0.821	24	0.001
No-tape	0.904	24	0.026
VMO			
Lateral	0.966	24	0.564
Medial	0.985	24	0.967
Neutral	0.973	24	0.729
No-tape	0.978	24	0.860
VL			
Lateral	0.965	24	0.555
Medial	0.956	24	0.361
Neutral	0.933	24	0.113
No-tape	0.972	24	0.709

This table illustrates the results of a Shapiro-Wilks test of normality for the normalised VMO, VL, and VMO/VL ratio obtained for the four experimental conditions. df = degrees of freedom.

for the medial (z = 2.714; $p = 0.007$) and neutral (z = 2.714; $p = 0.007$) conditions. The VM/VL ratio was greater for the lateral than for the no-tape condition, but this did not reach significance (z = 1.543; $p = 0.123$) (Table 4). The lateral condition had the greatest VM (F (3, 69) = 1.189;

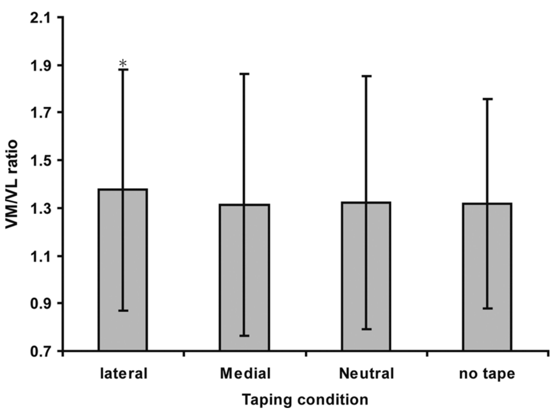

Figure 1. The VM/VL ratios for the four taping conditions. *The lateral condition was significantly different from the medial and neutral conditions. Data are provided as mean (1 SD).

Table 4. The difference between the VMO/VL ratio for the four experimental conditions.

	Lateral	Medial	Neutral	No-tape
Lateral		$p = 0.007$	$p = 0.007$	$p = 0.123$
Medial	Y		$p = 0.587$	$p = 0.407$
Neutral	Y	N		$p = 0.627$
NoTape	N	N	N	

Y = significantly different; N = not significantly different; p-values are also provided.

$p = 0.321$) and the smallest VL (F (3, 69) = 1.908; $p = 0.136$) activity, but neither was significantly different from the other conditions on their own.

The VM/VL ratio within subjects measurement error calculated from the four repeated squats during the no-tape condition was 0.113, which gave a repeatability value of ± 0.315 (0.113×2.77). Thus, the difference between repeated VM/VL ratio measurements for the same participant was expected to be $< \pm 0.315$ for 95% of observations. The VM/VL ratio reliability was also calculated from the four repeated squats during the no-tape condition with an $ICC_{(2,1)}$ value of 0.94 (95% CI 0.89–0.97).

Discussion

This study showed that laterally gliding the patella with tape during a static squat can significantly increase the VM/VL ratio compared with a medial ($p = 0.007$) and a neutral glide ($p = 0.007$). Laterally gliding the patella also increased the VM/VL ratio above that recorded when no tape was applied, but this did not achieve significance ($p = 0.123$) in this sample of 24 participants. This increased VM/VL ratio was achieved through a statistically nonsignificant increase in VM activity and a statistically nonsignificant decrease in VL activity for the lateral taping condition compared with the other taping conditions. However, the combined effect was statistically significant. The increase in VM/VL ratio for the lateral glide was approximately 5% above the three other conditions. This is the first time, to our knowledge, that the effects of a lateral glide on the VM/VL ratio during a single leg squat have been reported. This study also shows that the magnitude of the effect of taping on vasti activity is relatively small (~5%). Although such a change has been found to be statistically significant, it is doubtful that it would be clinically significant.

The VM/VL ratio within subjects measurement error and VM/VL ratio reliability were calculated from single measurements during the no-tape condition. The within subjects measurement error calculated for single measures was greater than the mean difference between conditions when the average of four measures was used. However, the mean differences between conditions proved statistically significant and relevant despite this finding as there was a generally consistent pattern of change between conditions for the average VM/VL ratio in most subjects. The reliability of the VM/VL data as single values was excellent $ICC_{(2,1)} = 0.94$. Considering that the values used in the study were averages, it is probable that the actual reliability of the data reported was >0.94. Hence, the reliability of the data was excellent, and the reported level of within subject measurement error was sufficiently low to allow an average value to be calculated from which relevant and statistically significant differences between conditions were detected.

Ng and Cheng (2002) explained the decrease in the VM/VL ratio caused by medial taping to the medial stabilising role of the VM and the medial stabilising effect of the tape. The authors postulated that if the patella were already medially stabilised there would be less need for the VM to be active relative to the VL. The results found in the present study could be explained in a similar manner. In the lateral glide, the VL needed to work less to stabilise the patella laterally, and the VM needed to increase its activity to medially stabilise the patella. The nonsignificant change recorded in each muscle contributed to a significant increase in the VM/VL ratio.

Limitations

First, the sample size used was relatively small. A larger sample size may have identified differences between the no-tape and lateral conditions for the VM/VL ratio. It may also have identified differences in individual vasti activity for the different conditions. Second, this study looked at an asymptomatic population. Thus, these data should not be extrapolated directly to the PFPS population. Future research should aim to replicate the current study with a large PFPS patient sample. In addition, future research needs to investigate the effect that skin perturbation may have on the recorded EMG signal, perhaps by using multiple electrodes placed on the muscle bulk. Finally, the force applied by the tape was not standardized by using a force transducer similar to the method of Ng and Cheng (2002), which could be regarded as the optimal way of doing so. However, in clinical practice, it is doubtful that a therapist would use a force transducer to measure the force applied to the tape; thus, the technique used in the study may be more reflective of clinical practice.

Conclusion

The magnitude of the change brought about by all taping conditions on the VM/VL ratio was small and of questionable clinical significance. This questions the purported ability of taping to increase VM activity relative to the VL. However, it should not be assumed that the vasti of PFPS patients will respond in a similar manner to lateral taping, or indeed any of the taping procedures utilised in this study; thus, this study needs to be repeated on a PFPS population before any clinical recommendations can be made.

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