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Immediate effect of anti-pronation foot taping on myoelectric activity of knee muscles in patellofemoral pain syndrome: a randomised controlled trial

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Abstract

Introduction. There is lack of studies on the effect of anti-pronation foot taping on the myoelectric activity of knee muscles. The purpose of this study was to investigate the immediate effect of anti-pronation foot taping on the myoelectric activity of the vastus medialis oblique and vastus lateralis muscles and their activity ratio in patellofemoral pain syndrome.

Methods. Twenty-six female patients were randomised into two equal groups. The study group A used augmented low Dye taping, while the control group B did not. The patients' age, weight, height and BMI ranged between 18–31 years, 50–73 kg, 1.53–1.72 m and 20–25 kg/m². All patients were evaluated twice; pre- and immediately post-foot taping (pre-test post-test control group design). Normalised data of the myoelectric activity of the knee muscles were recorded using a Neuro-EMG-Micro device during stair climbing and single leg mini-squat.

Results. The first 2 × 2 Mixed Design MANOVA revealed that the myoelectric activity of the vastus medialis oblique decreased significantly (p = 0.001) during both stair climbing and single leg mini-squat in group A post-taping compared with pre-taping. Similarly, the activity of the vastus medialis oblique decreased significantly (p = 0.019) post-taping in group A compared with group B during single leg mini-squat. The second 2 × 2 Mixed Design MANOVA test revealed that the activity ratio decreased significantly (p = 0.001) post-taping compared to pre-taping in group A during stair climbing.

Conclusions. Anti-pronation foot taping reduces the activity of the vastus medialis oblique during stair climbing and single leg mini-squat.

Key words: anterior knee pain, augmented low Dye taping, myoelectric activity, vastus medialis oblique, vastus lateralis

Introduction

Patellofemoral pain syndrome (PFPS) is one of the most common musculoskeletal disorders. Females are two times more likely to develop PFPS than males [1]. The annual prevalence of PFPS in the general population was reported to be 22.7%, with the annual prevalence in females 29.2% and males 15.5% [2]. The incidence rate over one season for female adolescent athletes is 14.9% [3]. Patients with PFPS present with anterior knee pain that is aggravated by activities that load the patellofemoral joint, such as stair climbing, squatting, and rising from sitting [4]. PFPS was previously suggested to run a benign and self-limiting course; however, there is evidence that PFPS contributes to the development of patellofemoral osteoarthritis in the long term [5, 6]. Conchie et al. [6] found that a patient with adolescent knee pain is 7.5 times more likely to develop patellofemoral osteoarthritis.

Several factors were found to contribute to the development of PFPS. Of these factors is a reduced vastus medialis obliquus (VMO) to vastus lateralis (VL) muscle activity ratio. Normally, both muscles function to stabilised the patella within the trochlear groove during tracking [7]. An electromyographic study of healthy individuals revealed that the VMO:VL ratio should be 1:1 [8]. VMO weakness or delay in activation disturbs patellar stabilisation, decreases medial patellar pull, and increases lateral patellar mal-tracking, which ultimately contribute to the development of PFPS [9, 10]. Pal et al. [10] found that VMO delayed activation is significantly related to patellar mal-tracking in one subset of patients with PFPS (those with patellar high tilt and bisect offset values).

Excessive rearfoot eversion (foot pronation) is also related to PFPS [11]. Excessive foot pronation increases tibial internal rotation, which is associated with compensatory increased femoral internal rotation and increased Q-angle. These postural changes cause lateral patellar tracking [11, 12]. As the patella tracks laterally over the femoral condyles, erosion of the patellar and femoral cartilage occurs. Excessive foot pronation also increases the stresses on the anterior cruciate ligament, rendering it more susceptible to injury [12]. Patients with PFPS show an earlier peak eversion angle during the stance phase compared with healthy individuals [13]. This causes higher and faster patellofemoral joint loads that aggravate PFPS development.

A variety of anti-pronation strategies were reported to be effective in controlling excessive foot pronation. These include taping and orthosis. According to a meta-analysis [14], therapeutic adhesive foot taping is more efficient than foot orthoses and motion control footwear in correcting foot position. The low Dye (LD) taping technique is one of the most popular techniques used by therapists for excessive subtalar pronation management [15].

A modified form of LD taping named Augmented LD taping (ALD taping) was found to reduce foot pronation by increasing the medial longitudinal arch height [16] and reducing rear foot motion [17]. In addition, it reduces the myoelectric activity of the tibialis anterior and posterior muscles [18]. Finally, it was found to be able to cause a delay in the onset of EMG signals of the gluteus medius, VMO, and VL muscles and an increase in the plantar pressure of the lateral midfoot during treadmill running in healthy individuals [19].

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It is believed that reducing excessive subtalar eversion and excessive tibial internal rotation and improving the VMO/VL activity ratio can help restore normal joint mechanics while avoiding developing a musculoskeletal disorder. For instance, Hyun-Hee and Chang-Ho [20] found that a neutrally positioned tibia, when squatting at 60° knee flexion, produced a significantly higher VMO/VL activity ratio than internally or externally rotated tibias in healthy individuals. Thus, one may assume that using anti-pronation foot taping to correct foot position may affect the myoelectric activity of the quadriceps muscles in patients with PFPS.

Due to the lack of studies investigating the effect of anti-pronation foot taping on the EMG activity of the quadriceps muscle in patients with PFPS, this study was conducted. The purpose of this study was to evaluate the immediate effect of anti-pronation foot taping on the EMG activity of the VMO and VL muscles, in addition to the VMO/VL activity ratio in patients with PFPS. The authors hypothesised that there would be no significant effect of anti-pronation foot taping on the myoelectric activity of the knee muscles in these patients.

Subjects and methods

Design

This study involved a pre-test post-test control group design.

Participants

An advertisement was placed on the Faculty of Physical Therapy of Cairo University social media groups for patient recruitment and at an orthopaedic clinic. A total of 32 patients volunteered to participate in the study. Twenty-six of these fulfilled the inclusion criteria and completed the study. The inclusion criteria were verified by a qualified physiotherapist. These criteria were: age ranging from 18 to 35 years, body mass index (BMI) ranging from 18 to 25 kg/m^2 as BMI affects the myoelectric amplitude [21], progressive onset of anterior knee or retropatellar pain for more than six weeks in one or both lower extremities, worst pain over the previous week of at least 30 mm on the 100 mm Visual Analogue Scale, pain caused by at least two of these activities (sustained sitting or kneeling, squatting, running, jumping, or stair climbing), tenderness on palpation of the patella, and bilateral pronated feet measured by the Foot Posture Index with a score ranging between +6 and +9 [22]. Patients were excluded from the study if they had any fracture or discomfort from the hip, lumbar spine, or other knee structures, previous knee surgery, patellofemoral instability, knee joint effusion, any foot disorder that could hinder the use of foot taping, any physiotherapy or foot taping procedure during the previous year, any neuromuscular disease, and/or any anti-inflammatory drug intake that is ongoing or in the two weeks before conducting the study. The specified inclusion and exclusion criteria were based on a previous clinical trial [23]. The patients were recruited with age ranging between 18 to 35 years as the risk of developing patellofemoral arthritis increases over the age of 40 [24] and we did not want to study patients with arthritis, being concerned with patellofemoral pain syndrome only. Figure 1 shows the CONSORT flow chart of the study. Our tested sample size (26 patients) produced a power level of 83% with an effect size of 0.75 calculated at an adjusted alpha level of 0.025.

Randomisation

Computer-based randomisation software divided the patients into two equal groups of 13 patients each. Group A used the ALD taping, while group B did not.

Instrumentation

A two-channel digital EMG device (Neuro-EMG-Micro, Neurosoft, Ivanovo, Russia) was used to test muscle activity during stair climbing and single leg mini-squat. The device has two silver surface recording electrodes (one active and the other passive) and a ground electrode. The electrodes were cup electrodes with a cup diameter of 100 mm, code DAGM 102600, and manufactured by Spes Medica, Italy. Electromyography can reliably reflect muscle strength and function through representing electrical potentials [25, 26]. The reliability of electromyography used to assess the amplitude and timing differences of the gluteus medius, VMO, and VL in patients with PFPS was examined by Bolgla et al. [27]. They [27] found that electromyographic measures had acceptable-to-moderate reliability, and low standard errors of measurements, which suggest high measurement precision.

Static foot posture was assessed using the six-item Foot Posture Index [22]. Scores ranging from +2 to −2 were given for each of: talar head position, supra and infra malleolar curvature, calcaneal frontal plane position, talonavicular joint prominence, medial longitudinal arch congruence, and abduction/adduction of the forefoot on the rearfoot. A score from −12 (highly supinated) to +12 (highly pronated) was obtained with scores from 0 to 5 indicating normal foot posture, + 6 to + 9 pronated, 10+ highly pronated, −1 to −4 supinated and −5 to −12 highly supinated. The Foot Posture Index has moderate to good reliability and its content, construct, criterion, and predictive validity are acceptable as a simple-to-use, cost-effective, clinical measurement tool that can be used for screening, diagnosis and prognosis for most disorders of the foot and ankle [28].

The tape used in the study was a rigid sport tape (38 mm zinc oxide adhesive, Leukosport BDF). A hypo-allergic undertape (Fixomull ®Stretch; BSN medical GmbH, Hamburg, Germany) was applied first to cover the foot and lower third of the leg to prevent any allergic reaction.

Procedures

The study was performed at the Electromyographic (EMG) Laboratory in the Faculty of Physical Therapy of Cairo University. The nature, aim, and procedures of the study were clarified for each patient. They were told that they have the right to decline or withdraw at any time. Patients were assessed for the myoelectric activity of the VMO and VL muscles during two functional tasks (stair climbing and single leg mini-squat) before and 10 min after foot taping.

Four recording electrodes (two active and two reference) were applied unilaterally on the VMO and VL muscles on the affected lower limb in patients with unilateral affection and on the most symptomatic limb in patients with bilateral affection. Initially, alcohol was used to remove the debris from the skin that overlied the muscles and tibial tuberosity. The VMO electrode was placed approximately 4 cm superior and 3 cm medial to the upper medial border of the patella, oriented 55° to the vertical [29]. The VL electrode was placed 5–7 cm superior and 6–8 cm lateral to the upper lateral border of the patella, oriented 15° to the vertical [30]. The ground electrode (5th electrode) was placed and secured to the tibial tuberosity.

For better fixation, the electrodes were fixed with a self-adhesive tape and then wrapped in an elastic bandage.

After electrode placement, the myoelectric activity during maximum voluntary isometric contraction (MVIC) was assessed during a five second period. To prevent exhaustion, the patient performed three MVIC trials and rested for one minute between each two successive trials. To help the patient conduct an MVIC, patients were encouraged to exert their maximum effort as the investigator gave a clear verbal order and encouragement. With the patient sitting at 90° hip flexion and 60° knee flexion, maximum manual resistance was applied just above the malleoli, and the MVICs of the selected muscles were measured [31].

The patients were instructed to perform the two functional tasks – stair climbing and single leg mini-squat – in a random order selected by coin toss. These tasks were tested because patients with PFPS commonly report symptoms when performing these tasks [4]. All patients were instructed to do these tasks while wearing identical flat shoes that were provided to all of them. For stair climbing, the patient ascended a four-step wooden staircase with a step height of 20 cm, ensuring that each patient started stair climbing with the tested lower limb (Figure 1). Since the myoelectric activity is influenced by movement velocity, each patient performed the task at a rate of 96 beats per minute, as measured by a metronome [29]. Only the EMG data recorded while the patient ascended the third step in the 'step-up' task were used for analysis.

Figure 1. Myoelectric activity recording during stair climbing

For the single leg mini-squat, each patient stood on her tested lower limb. She was instructed to flex the hip, knee and ankle joints moving down into a mini-squat position, with the extended non-stance lower limb reaching anteriorly and descending as far as possible in one second (descending phase). She was instructed to hold this mini-squat position of the tested limb for one second, with the non-stance limb tapping the ground gently (holding phase). Finally, she was instructed to return to the starting position in one second (ascending phase). EMG data were recorded throughout the entire task [32]. Figure 2 presents the three phases of the mini-squat.

Each of the two functional tasks was repeated three times with a two-minute rest period between each two trials. A four-minute rest period was given to the patients between the two tasks. EMG data were collected for both groups twice. Group A was tested pre- and post-foot taping, while group B was tested at the same time intervals without taping or any other intervention. Both groups were allowed to walk freely for 10 minutes between the pre- and post-testing periods.

Tape application

For group A, the ALD taping was applied to all patients bilaterally by the same physiotherapist. The ALD taping involves low Dye (LD) taping augmented by three reverse sixes and two calcaneal slings. The LD taping itself consists of spurs and mini-stirrups. ALD taping was chosen as it was found recently to be the most efficient taping technique that controls foot arch collapse immediately post-taping, compared to baseline [33]. The tape was applied with the patient supine lying and the foot suspended over the end of the supporting table. The foot was initially positioned in a neutral talocrural joint and slightly supinated subtalar and midtarsal joints [16]. This foot position was maintained while taping. An experienced therapist applied the tape for all the patients. The application of LD taping (spurs and mini-stirrups) was followed as described by Vicenzino et al. [16]. The spurs are anchors circulating around the foot starting on the medial aspect of the foot just proximal to the first metatarsophalangeal (MTP) joint, moving proximally with some sort of traction to limit forefoot abduction (a component of abnormal prona-

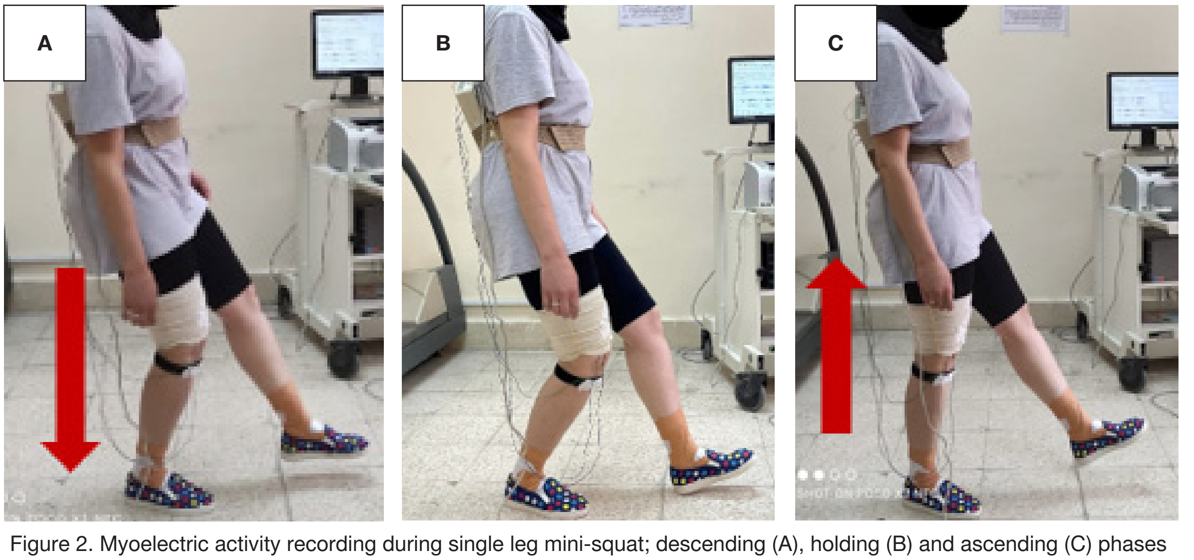

Figure 2. Myoelectric activity recording during single leg mini-squat; descending (A), holding (B) and ascending (C) phases

Figure 3. Augmented low Dye taping technique used in the study

tion), passing around the heel, moving distally along the lateral aspect of the foot reaching just proximal to the fifth metatarsophalangeal joint. The mini-stirrups are several stirrups that overly each other with each stirrup starting on the lateral aspect of the foot anchoring on the lateral aspect of the spur, moving medially across the sole of the foot and ending on the medial aspect of the foot and anchoring on the medial aspect of the spur, again with some sort of traction to limit pronation. Each stirrup covers the previous distal one by about half its width. Application of stirrups continues in a proximal direction until it covers the calcaneus. Finally, another spur is applied to lock off all the mini-stirrups.

As mentioned above, we used ALD taping in our study, and this taping technique requires application of LD taping in addition to reverse sixes and calcaneal slings. The reverse sixes and calcaneal slings were anchored to the lower third of the leg. The reverse sixes involve applying a tape starting from the medial distal tibia moving downwards to the lateral side of the calcaneus, taking the calcaneus in inversion and ending up at the medial side of the distal tibia. The calcaneal sling involves applying tape starting from the lateral distal tibia moving downwards towards the medial aspect of the tibia to the medial aspect of the calcaneus then over the posterior aspect of the calcaneus to the lateral aspect of the calcaneus down to the inferior aspect of the calcaneus taking the calcaneus in inversion while passing over the medial aspect of the calcaneus and crossing up laterally to end up at the lateral aspect of the distal tibia [34]. Figure 3 shows the ALD taping technique used in the study.

EMG data analysis

The Neuro-EMG-Micro EMG device was used to record the EMG signals and the root mean square (RMS) was calculated and used for analysis. The RMS was chosen as it reflects the level of physiological activity in the motor unit during contraction [35]. The outcome measures were the RMS values of the myoelectric activity of the VMO and VL muscles as well as the VMO/VL muscle ratio during stair climbing and single leg mini-squat. For each muscle, the maximum RMS values of all three MVIC trials were averaged and used for normalisation. For each of the two tasks, the maximum RMS values of all three trials for each muscle (VMO & VL) were averaged and the average score divided by its respective averaged maximum MVIC value [32]. All dependent values were in the form of normalised values that were expressed as percentages of maximum EMG activity using the following equation.

$$\text{Normalised RMS} = \frac{\text{average RMS during activity}}{\text{average RMS of MVIC}} \times 100$$

Statistical analysis

The patients' demographic data, including age, weight, height, and BMI of the two groups, were compared using unpaired *t*-tests. A 2 × 2 Mixed Design MANOVA was used to evaluate the effects of between-subject comparison and within-subject comparison of the myoelectric activity of the VMO and VL muscles. Another 2 × 2 mixed design MANOVA was used to evaluate the effects of the between-subject comparison and within-subject comparison of the VMO/VL ratio. Two separate 2 × 2 Mixed Design MANOVAs were used as the VMO/VL activity ratio depends on the values of the VMO and VL activity for its calculation. The significance level was set at 0.025 (0.05/2) as two tests were used. This Bonferroni adjustment of the alpha level was conducted to avoid alpha inflation and committing a type-I error. The statistical package for social sciences (SPSS) version 22 for Windows (IBM SPSS, Chicago, IL, USA) was used to perform all the statistical tests.

Results

The patients' demographic data were compared between both groups. The age was 22.62 ± 3.1 vs 22.62 ± 4 years, weight 60.85 ± 5.4 vs 62.15 ± 6.12 kg, height 1.62 ± 0.05 vs 1.64 ± 0.05 m, and BMI 23.2 ± 1.3 vs 22.94 ± 1.04 kg/m^2 for group A vs group B, respectively. Unpaired *t*-tests revealed no significant differences between both groups for the demographic data ($p > 0.05$). There was no patient drop-out throughout the study with the commitment rate being 100% because it was a single session study and there were no adverse effects of the tape application. Figure 4 presents the CONSORT flow chart of the study.

The first 2 × 2 Mixed Design MANOVA showed that the VMO activity decreased significantly ($p \leq 0.001$) at post-test compared with pre-test during both stair climbing and squatting in group A. The VMO activity again decreased significantly in group A compared with group B at post-test during squatting with no other significant differences being reported.

The other 2 × 2 Mixed Design MANOVA showed that the VMO/VL activity ratio decreased significantly in post-test compared with pre-test in group A during stair climbing. No other

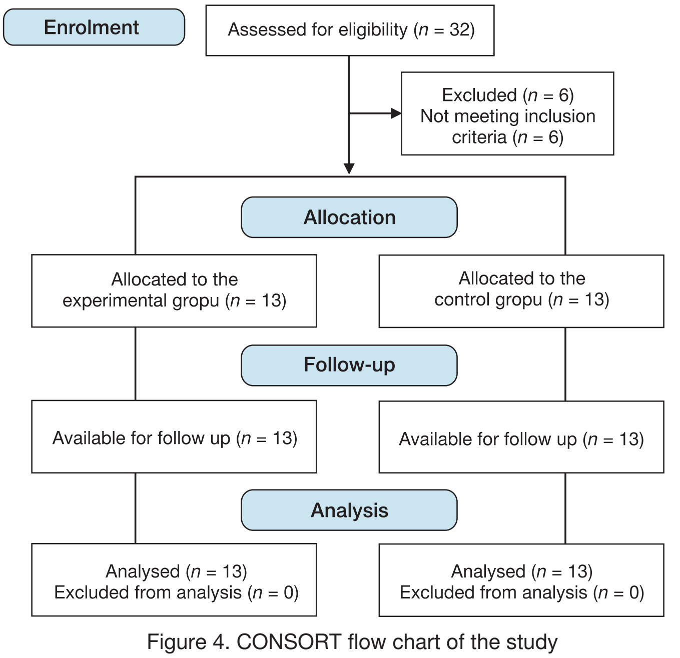

Figure 4. CONSORT flow chart of the study

Table 1. Descriptive statistics of the vastus medialis obliques, vastus lateralis, and their ratio during stair climbing and squatting in both tested groups

Dependent variable	Tape group (group A) mean ± *SD*		Control group (group B) mean ± *SD*	
	pre-test	post-test	pre-test	post-test
VMO stair climbing (%MVIC)	280.73 ± 108.95	203.47 ± 82.18	273.27 ± 63	253.72 ± 45.95
VMO squat (%MVIC)	137.98 ± 26.24	114.19 ± 31.94	132.59 ± 32.28	144.2 ± 21.74
VL stair climbing (%MVIC)	226.41 ± 125.78	257.32 ± 181.89	213.65 ± 88.6	224.45 ± 99.32
VL squat (%MVIC)	132.57 ± 19.14	129.29 ± 32.96	129.96 ± 21.64	131.95 ± 9.93
VMO/VL ratio stair climbing	1.17 ± 0.36	0.81 ± 0.26	1.27 ± 0.4	1.12 ± 0.39
VMO/VL ratio squat	1.03 ± 0.24	0.95 ± 0.4	1.04 ± 0.16	1.13 ± 0.2

VMO – vastus medialis oblique, VL – vastus lateralis

Table 2. 2 × 2 Mixed Design MANOVA with subsequent multiple comparison tests between both tested groups for the quadriceps muscle activity during stair climbing and squatting pre-test and post-test

	Time of testing	Task performed	Dependent variable	Sig.	97.5% confidence interval for difference	
					lower bound	upper bound
Group A vs group B	Pre-test	Stair	VMO	0.85	–86.06	100.98
			VL	0.79	–100.29	125.8
			VMO/VL	0.56	–0.51	0.31
		Squat	VMO	0.66	–24.04	34.81
			VL	0.76	–17.95	23.17
			VMO/VL	0.89	–0.22	0.2
	Post-test	Stair	VMO	0.098	–120.33	19.83
			VL	0.61	–121.56	187.29
			VMO/VL	0.06	–0.67	0.06
		Squat	VMO	0.019*	–58.46	–1.55
			VL	0.81	–28.8	23.48
			VMO/VL	0.17	–0.51	0.14

Sig. – significance, Group A – tape group, group B – control group, VMO – vastus medialis oblique
VL – vastus lateralis, VMO/VL – vastus medialis oblique to vastus lateralis ratio
* significant at $p < 0.025$

Table 3. 2 × 2 Mixed Design MANOVA with subsequent multiple comparison tests between both times of testing for the quadriceps muscle activity during stair climbing and squatting in both tested groups

	Tested group	Task performed	Dependent variable	Sig.	97.5% Confidence interval for difference	
					lower bound	upper bound
Pre-test vs post-test	Group A	Stair	VMO	0.000*	34.83	119.69
			VL	0.08	–70.78	8.96
			VMO/VL	0.001*	0.12	0.58
		Squat	VMO	0.001*	9.47	38.1
			VL	0.56	–9.91	16.46
			VMO/VL	0.28	–0.096	0.26
	Group B	Stair	VMO	0.34	–28.83	67.93
			VL	0.57	–56.26	34.66
			VMO/VL	0.09	–0.05	0.35
		Squat	VMO	0.1	–27.93	4.71
			VL	0.75	–17.02	13.04
			VMO/VL	0.16	–0.25	0.06

Sig. – significance, VMO – vastus medialis oblique, VL – vastus lateralis, VMO/VL – vastus medialis oblique to vastus lateralis ratio
* significant at $p < 0.025$

significant differences were found. Tables 1–3 show the recorded mean ± *SD* of the EMG activity of the tested muscles during both stair climbing and squatting, as well as the above statistical findings.

Discussion

The findings of the current study revealed that there was a significant decrease in the myoelectric activity of the VMO muscle during stair climbing and mini-squat immediately post-taping compared with pre-taping in group A. The decrease in muscle activity can be explained by the indirect effect of anti-pronation foot taping on the quadriceps muscle activity. Anti-pronation foot taping was found to reduce the activity of the tibialis anterior muscle by increasing the medial longitudinal arch height [18]. The decrease in tibialis anterior activity is associated with a decrease in VMO activity [36]. Choi et al. [36] found that the VMO muscle activity during straight leg raising with hip external rotation and ankle dorsiflexion (i.e. with increased activity of the tibialis anterior) was significantly greater than that during straight leg raising with hip external rotation only, without dorsiflexion. The researchers [36] attributed this to the concept of 'irradiation'. Irradiation refers to the activation of weak or injured muscles through stimulation of strong and preserved muscles, thus facilitating muscle contraction [37]. Accordingly, the significant effect of anti-pronation foot taping on decreasing the VMO myoelectric activity might have happened due to the effect of anti-pronation foot taping on reducing the activity of the tibialis anterior muscle.

The significant reduction in VMO activity post-taping during stair climbing reported in our study contradicts the findings of Lack et al. [38]. The latter [38] investigated the immediate effect of prefabricated foot orthoses on the myoelectric activity of the VMO, VL and gluteus medius muscles during a functional step-up task. EMG was assessed with and without anti-pronation foot orthoses in patients with PFPS. A decreased gluteus medius peak amplitude was observed after ground contact in the 'with orthosis' condition with no significant change in the VMO or VL activity. The difference between our findings and their findings might be attributed to the fact that all our patients were with pronated feet while in their study, they examined patients with different foot conditions. In addition, they used an anti-pronation foot orthosis while we used anti-pronation foot taping. Differences among foot orthoses, motion control footwear, therapeutic adhesive taping and no-intervention conditions in correcting foot pronation were investigated by a meta-analysis [14]. This meta-analysis concluded that all three interventions were able to control rearfoot eversion, with the therapeutic adhesive taping being the most effective.

In 2007, Ribeiro et al. [39] examined the effect of different foot positions on the myoelectric activity of the VMO, VL, rectus femoris, biceps femoris, lateral gastrocnemius and tibialis anterior muscles during squatting. They assessed five forms of foot positions (neutral position, under a 10° anteroposterior descending wedge, 10° anteroposterior ascending wedge, 10° medial wedge and 10° lateral wedge). They found no significant difference among the five foot positions in the myoelectric activity values of all muscles. Their findings are in agreement with ours because they found no significant changes in the VL EMG between the 10° lateral wedge (pronated foot) and the neutral position. However, their findings differ from ours in that they found no significant changes in the VMO EMG, in contrast to our findings, which revealed a significant reduction post-taping during the mini-squat. The lack of significance reported by Ribeiro et al. [39] may be attributed to their small sample size (eight individuals only) and their tested healthy individuals who are anticipated having no affection of the quadriceps muscle activity/balance, especially VMO activity.

Regarding the VMO/VL ratio tested in our study, it decreased post-taping compared to pre-taping during both stair climbing and mini-squat in group A only; however, the decrease was not statistically significant during the mini-squat. This decrease may be related to the decrease in the VMO activity post-taping compared to pre-taping in both tasks in group A with no significant change in the VL activity post-taping. This is in contrast to Miller et al.'s [40] findings. They assessed the VMO/VL activity ratio during a step-up/step-down task with the leg placed in three different positions (neutral position and medial and lateral rotation) and found no significant difference in VMO/VL ratio during this step-up/step-down task among the three tested conditions. During closed-kinetic chain movement, as the foot pronates, the tibia internally rotates and as the foot supinates, the tibia externally rotates [41]. In our study, moving the pronated feet of our patients into supination by taping resulted in a decreased VMO/VL ratio, in contrast to Miller et al. [40], who found no significant difference in changing the leg position. The difference between our findings and theirs may be due to several issues. First, Miller et al. [40] recorded the EMG data while stepping down and stepping up, which required both eccentric and concentric quadriceps contraction, whereas we recorded the EMG while stepping up only, which required only concentric quadriceps contraction. Second, Miller et al. [40] asked their participants to perform the task with the toes pointing straight forwards without rotation of the tibia or femur, with the toes pointing inwards 45° with the tibia and femur being medially rotated and with the toes pointing outwards 45° with the tibia and femur being externally rotated. All these postural restrictions/adjustments were not considered in our study; we just allowed our patients to ascend the stairs in their usual, natural way. Finally, Miller et al. [40] examined only six individuals, which is considered a small sample size and might have caused a loss of statistical significance.

Finally, the findings of our study revealed that there was a significant decrease in the VMO myoelectric activity post-taping in group A compared with group B during the mini-squat only, while there was no significant difference during stair climbing. The difference between both groups during the mini-squat is related to the tape application, which, as stated before, has an indirect effect on the VMO muscle activity. As mentioned earlier, taping reduces the tibialis anterior activity by increasing the medial longitudinal arch and this reduced activity is associated with reduced VMO activity [36].

The decreased VMO activity recorded during mini-squat only, but not reported during stair climbing, might be related to the difference in the type of quadriceps muscle contraction between both exercises. In our study, the EMG was recorded during the pull-up phase of the stair climbing 'step up' task, which mainly requires concentric quadriceps contraction [42], while the EMG was recorded throughout the whole mini-squat phases. The mini-squat descending phase required eccentric quadriceps contraction, the hold phase isometric contraction, and the ascending phase concentric contraction [42]. The latter [43] defined the eccentric phase as that period when the participant moved from full knee extension to 90° knee flexion and the concentric phase as that period when the participant moved from 90° knee flexion to full extension.

Comparing the concentric step-up phase of stair climbing with the eccentric descending phase of mini-squat, it is accepted that the EMG activity during the mini-squat will be lower than that of stair climbing. Westing et al. [44] found that the EMG activity level of the knee extensors (VM, VL and rectus femoris) is significantly lower in eccentric contraction compared with concentric contraction (7–31%) measured at the same velocity. Enoka [45] attributed the lower activation level of eccentric contraction to the unique activation strategy used by the nervous system for eccentric activation. This strategy involves reduced muscle activation during maximum eccentric contraction, altered recruitment order of motor units during submaximal eccentric contraction, decreased size of the potentials evoked in the muscles by transcranial and peripheral nerve stimulation during eccentric contraction, and greater resistance to fatigue through reduced muscle force during repeated contractions. The reduced neural drive to the agonists in eccentric contraction suggests the presence of an inhibitory mechanism that helps protect the musculoskeletal system from injury that might occur when the muscle is fully activated [44].

On the other hand, comparing the concentric step-up phase of stair climbing with the concentric ascending phase of the mini-squat, it is accepted that the EMG activity level during the mini-squat is lower than that during stair climbing. This is attributed to the EMG activity level that decreases as the concentric velocity decreases [44]. Our stair climbing task was recorded at 96 beat/min, while the mini-squat was recorded at 60 beat/min.

Based on our findings, our hypothesis is rejected, as we found a significant reduction in VMO activity post-taping in both tasks. This is in addition to the reduction in the VMO/VL activity ratio reported post-taping, again in both tasks, although being not statistically significant during the mini-squat. This reduction in VMO activity immediately after tape application may help athletes during sporting activities. It may help reduce muscle fatigue. Future studies investigating the long-term effect of ALD taping on the myoelectric activity of the VMO and VL muscles and their ratio are to be conducted on male populations and larger sample sizes. This study is limited by the small sample size, inability to generalise the findings to the male population as the tested sample involved female patients only, and absence of day-to-day participant activity control.

Conclusions

Anti-pronation foot taping (augmented low Dye taping) decreases the myoelectric activity of the VMO muscle during stair climbing and single leg mini-squat.

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Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Institutional Ethical Review Board of the Faculty of Physical Therapy of Cairo University (approval No.: P.T.REC/012/00906).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Disclosure statement

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Conflict of interest

The authors state no conflict of interest.

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