

**THE EFFECT OF MEDIAL PATELLAR TAPING ON  
PAIN, STRENGTH AND NEUROMUSCULAR  
RECRUITMENT IN SUBJECTS WITH AND  
WITHOUT PATELLOFEMORAL PAIN**

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## DEDICATION

To my mother and soulmate, Helen,  
for lifelong friendship:

being able to sift my words, both chaff and grain,  
keep what is worth keeping, and with love and “the breath of kindness,  
to blow the rest away.”

GEORGE ELLIOT

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- My God and Creator, for ALL I have and am

## DECLARATION

I, Janet Helen Loudon Brown, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise), and that neither the whole work, nor any part of it, has been, is being, or is to be submitted for another degree in this or any other university.

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## ABBREVIATIONS

ANOVA (Analysis of variance)

EMG (Electromyography)

MIVC (Maximum isometric voluntary contraction)

PFJRF (Patellofemoral joint reaction force)

PFPP (Patellofemoral pain)

PFPS (Patellofemoral pain syndrome)

SD (Standard deviation)

VAS (Visual analogue scale)

VL (Vastus lateralis)

VM (Vastus medialis)

VML (Vastus medialis longus)

VMO (Vastus medialis oblique)

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# CHAPTER 1

## INTRODUCTION AND SCOPE OF THESIS

Patellofemoral disorders are amongst the most common clinical conditions encountered in the sporting and general population.<sup>8,33,68</sup> Patellofemoral pain (PFP) is usually described as diffuse, peripatellar, anterior knee pain.<sup>8,61</sup> Symptoms are typically aggravated by activities such as stair ascending or descending, squatting, kneeling, running and prolonged sitting.<sup>8,68,73</sup> The most common reasons for development of anterior knee pain are patellofemoral malalignment, overuse and trauma. Factors predisposing a person to PFP include abnormal biomechanics, soft tissue tightness, muscle dysfunction and training errors.<sup>8</sup>

A wide variety of disorders may all fall under the 'umbrella' term of PFP. As a result, a thorough systematic evaluation of the patient's lower extremity alignment, patellar mobility, muscle flexibility, strength, coordination, soft tissue and articular pain is important in determining the causes of PFP and in prescribing an optimal rehabilitation programme. Management of patellofemoral pain syndrome (PFPS) often includes reduction of pain and inflammation through cryotherapy, heat therapy, massage therapy muscle flexibility and strength training (especially quadriceps), patellar taping, bracing, orthotics, correction of abnormal biomechanics or other causative factors, acupuncture, and surgery.

Patellar taping is used by clinicians during the treatment of PFP, in an attempt to reduce pain, increase strength, enhance neuromuscular recruitment and to correct the timing of onset of activation of vastus medialis oblique (VMO).<sup>8,18,73</sup> Patellar taping in the treatment of PFP is most commonly applied directly over the patella with a force aimed at pulling the patella into a medial position.<sup>73</sup> Many hypotheses for the mechanism of action of the patellar tape have been proposed and include: 1) pain inhibition,<sup>3,6,11,13,18,19,20,29,37,40,46,47,48,73,74,84,94</sup> 2) reduction of reflex inhibition of the quadriceps with a resultant increase in peak torque,<sup>13,46,47</sup> 3) altered quadriceps muscle recruitment,<sup>40,73</sup> 4) improved patellar tracking by repositioning the patella within the trochlear groove with resultant decreased load on the patellofemoral joint,<sup>17,73</sup> 5) alteration of compensatory gait strategies,<sup>84,94</sup> 6) enhanced proprioception,<sup>31</sup> and 7) the placebo effect of a clinical intervention.

The literature is unclear on the effect of tape on pain, strength, EMG activity, patellar position, gait and proprioception. Further research is necessary to identify the mechanisms by which various taping procedures influence patellofemoral joint mechanics in order to appreciate the clinical value of the use of tape in alleviating symptoms associated with PFP.

The aim of this thesis was to review the current literature on: 1) the differences between PFP subjects and the normal population regarding strength and neuromuscular recruitment, 2) the effects of tape on subjects with patellofemoral pain. Thereafter, to undertake a research study to investigate: 1) any differences in strength and

neuromuscular recruitment between subjects with PFP and the normal population, 2) the effect of medial patellar taping on pain, strength and neuromuscular recruitment (quantity and time of onset of EMG activity) during open chain and closed chain exercises in subjects with and without patellofemoral pain.

This thesis is presented in the format of two papers that are to be submitted for publication in relevant sports medicine journals. The first paper (chapter 2) is the review of patellofemoral pain and the effects of patellar taping. The second paper (chapter 3) is the original research paper entitled: "The effects of medial patellar taping on pain, strength and neuromuscular recruitment in subjects with and without patellofemoral pain".

## **CHAPTER 2**

### **REVIEW PAPER**

#### **A REVIEW OF PATELLOFEMORAL PAIN AND THE EFFECTS OF PATELLAR TAPING**

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## 2.1 INTRODUCTION

The patellofemoral joint has been described as the most researched small joint in the body, producing pain and disability far out of proportion to its size.<sup>38</sup> Patellofemoral disorders are amongst the most common clinical conditions encountered in the sporting and general population, occurring particularly in tasks that involve repetitive loading of the lower limb.<sup>8,33,68</sup>

Patellofemoral pain syndrome (PFPS) is reported to affect one in four of the general population<sup>73</sup> and accounts for one quarter to one third of all complaints of knee pain in active athletes.<sup>21,102</sup> Regarding gender differences and the incidence of PFPS, in the general population, two females are affected with PFPS for every male, however when athletes are studied, men are shown to outnumber women.<sup>65</sup> Despite this high incidence, the exact cause of these disorders remains obscure. Numerous mechanisms have been described by which patellofemoral pain (PFP) might be induced.<sup>8,34</sup> The patellofemoral joint is often subject to direct trauma, possibly due to its prominent nature, as well as indirect trauma from the tremendous forces generated at this joint during repetitious functional activities.

This article aims to review the factors associated with patellofemoral pain syndrome and the management of this dysfunction with particular reference to patellar taping.

## 2.2 ANATOMY AND BIOMECHANICS

### 2.2.1 Patellofemoral Joint

The patella is the largest sesamoid bone in the body.<sup>38</sup> It is situated anterior to the femur within the tendons of the quadriceps (vastus intermedius, vastus lateralis, vastus medialis and rectus femoris) at the point where they converge on the dorsal surface of the patella before inserting into the tibial tuberosity via the patella tendon.<sup>43</sup> The patella is reported to increase knee extension moment by as much as 50%.<sup>42</sup> It guides the forces of the quadriceps femoris components to the patella ligament, protects deeper knee joint anatomy, protects the quadriceps tendons from frictional forces and increases the compressive forces to which the extensor mechanisms can be subjected.<sup>35,42</sup>

The articular cartilage of the patella exhibits unusual features in that it is extraordinarily thick (up to 7 mm) and exhibits multiple facets unique to each individual, which do not follow the contour of the underlying bone. In addition, the material properties of this articular cartilage vary throughout the surface and differ significantly from the underlying femoral trochlear cartilage.<sup>1</sup> During much of the range of knee flexion, the patella is in contact with the underlying femoral trochlear, which is a cartilage-covered groove in the distal femur. Two femoral condyles, one medially and one laterally, form the walls of this groove.

The stability of the patellofemoral joint is dependent on both static and dynamic mechanisms.<sup>56</sup> The lateral wall of the femoral groove is more prominent anteriorly and

imparts a static restraint on the patella's tendency to track laterally. Other static restraints include the bony configuration of the patella and tibia. The capsule of the knee, which is thickened (laterally more so than medially) to form the patellofemoral ligaments, acts as a passive stabilising force on the patella.

### 2.2.2 Musculature

Dynamic stabilisation is performed anteriorly by the four main quadriceps muscles, and indirectly via the hamstrings, adductor magnus and iliotibial band.<sup>38</sup> The main force-producing muscles, which on contraction produce knee extension are rectus femoris, vastus intermedius, vastus medialis and vastus lateralis.<sup>66</sup> The vastus medialis oblique (VMO) appears to perform a more stabilising function to the patellofemoral joint.<sup>5,66</sup>

The vastus medialis (VM) muscle can be divided into two parts namely, the vastus medialis longus (VML) and the VMO. As the names suggest, the VML lies longitudinally, at 15-18° medially to the shaft of the femur, whereas the VMO fibres run obliquely, at 50-55° medially, to the shaft of the femur. The vastus lateralis lies 12-15° laterally to the shaft of the femur. The rectus femoris lies 7-10° medially and the intermedius parallel to the shaft of the femur.<sup>66</sup> A larger percentage of type 1 fibres are found in the VM (61.5 %) compared to the VL (46.9 %).<sup>55</sup> Therefore, the VM possibly functions as a primary postural (tonic) muscle providing active stability to the patellofemoral joint.<sup>91</sup> The rectus femoris is the faster component (dynamic, phasic) of the quadriceps group and has a larger proportion of type 2 fibres.<sup>55,90,91</sup> The femoral nerve

supplies all the quadriceps muscles. An additional nerve supply to the VMO arising from the saphenous nerve has been isolated.<sup>45</sup>

### 2.2.3 Patellar Tracking

Patellar tracking is the alignment of the patella as it moves in the intercondylar groove during knee flexion and extension. Patellar tracking appears to be most affected by the bony configuration of the femoral condyles and patella.<sup>87</sup> Bony stability at the end range of knee extension may be compromised in some individuals as a result of a shallow intercondylar groove which has been implicated as contributing to abnormal patellar alignment and possibly PFP.<sup>87,95</sup> Patellar tracking appears to be less affected by quadriceps contraction when the knee is flexed greater than 30°.<sup>24</sup> This is as a result of an increase in the stability of the patella as it is drawn deeper into the intercondylar groove by the increasing tension within the extensor mechanism.<sup>52,97</sup> Abnormal patellar tracking (lateralised and or tilted patella, medial or lateral patellar subluxation, lateral patellar dislocation) was evident in 80% to 90% of PFP subjects in previous studies.<sup>95,97</sup> Most lateralised patellae become congruent at 30° knee flexion due to increased bony stability.<sup>95</sup> This highlights the importance of the use of magnetic resonance imaging (MRI) or computerised tomography (CT) scan in evaluation of patients with PFP, particularly in the first 30° of knee flexion where conventional axial radiographs are limited due to inability to clearly visualise structures.

VM has the fibre orientation to provide a medial force to the patella.<sup>66</sup> Therefore, it has been suggested that atrophy of the VMO and ensuing weakness was the cause of lateral

patellar tracking.<sup>73</sup> Lieb and Perry<sup>66</sup> show that simulation of the force of VMO cannot generate knee extension, indicating that the role for this muscle is not as a knee extensor, but more likely for medial patellofemoral control. However, the findings of Lieb and Perry<sup>66</sup> also suggest that early atrophy of the VMO prominence and loss of terminal knee extension are indicative of general quadriceps weakness rather than of a deficiency localised to the VMO. The prominence of the VMO may be attributed to the thinness of its fascial covering and obliquity of its fibers, therefore fluctuation in its size is the most visible of all the quadriceps muscles. The action of the VMO seemed to have the most significant effect on patellar alignment in relation to the efficiency of the VL.<sup>66</sup>

#### 2.2.4 Patellofemoral Joint Reaction Force (PFJRF)

The patellofemoral joint is subjected to loads of several times the body weight during loaded knee flexion activities.<sup>72</sup> Forces can reach three times the body weight during stair ambulation and eight times the body weight whilst performing a squat.<sup>72,88</sup> This compression force of the ventral surface of the patella against the femoral condyles is called the patellofemoral joint reaction force (PFJRF). The magnitude of the PFJRF depends on the tension in the quadriceps muscle, the angle of knee flexion and the patellar tendon tension.<sup>88</sup> During a closed chain movement (for example, a squat in standing), PFJRF increases with increasing knee flexion from 0° to 90°. However, during an open chain movement (for example, knee extension from sitting using a weighted boot), PFJRF increases with knee extension from 90° to 45°.<sup>43,52,99</sup> At 0° the quadriceps force is high but the PFJRF is low as the femur and tibia are nearly parallel and there is no contact between the two cartilaginous surfaces.<sup>43</sup>

### 2.2.5 Patellofemoral Contact Area

The patellofemoral contact area is the area on the ventral surface of the patella that is in contact with the femoral condyles during knee flexion. It is the area over which the PFJRF is applied during knee movement. At full extension there is no contact of the patella on the femur. The first contact occurs along the inferior pole of the patella between 10° and 20° of knee flexion. The overall patellofemoral contact area increases with the degree of flexion from 2.0 cm<sup>2</sup> at 30° flexion to 5.0 cm<sup>2</sup> at 90° flexion.<sup>52</sup>

### 2.2.6 Patellofemoral Contact Stress

Patellofemoral contact stress refers to the unit load (kg) applied to contact area (cm<sup>2</sup>) of the ventral surface of the patella during knee movements. As for PFJRF, contact stress increases with knee flexion from 0° to 90° under body weight,<sup>43,108</sup> and increases with knee extension from 90° to 25° during an open chain movement.<sup>43</sup> At 0° there is no contact between the two cartilaginous surfaces of the femur and patella therefore contact stress is low.<sup>43</sup> A large PFJRF and contact stress applied over a small surface area may overload the tissue and result in a knee injury. This has important implications in the etiology and rehabilitation of patients with PFP.

### 2.2.7 Predisposing Factors to PFP

Both intrinsic and extrinsic risk factors may increase the PFJRF and contact stress or alter patellar tracking thus predisposing an individual to PFP.<sup>105,114</sup> Intrinsic risk factors relate to individual physical characteristics and psychological traits, whereas extrinsic risk

factors are related to factors outside the human body, such as the type of sports activity, the biomechanics of the sport, the environmental conditions and the equipment used.

Intrinsic factors that may affect patellar tracking include: the shape, size (small) and position (high riding) of the patella, the shape of the femoral condyles (producing a shallow intercondylar groove), an increased angle of pull of the quadriceps (Q angle), excessive subtalar joint pronation, leg length discrepancies, imbalances in muscle strength and control and musculotendinous inflexibility.<sup>8,87,105,114</sup> In a two year prospective study on an athletic population only four factors showed a significant correlation with the incidence of PFP: a shortened quadriceps muscle, altered VMO reflex response, decreased explosive strength and a hypermobile patella.<sup>114</sup> Interestingly, this study did not identify any lower leg alignment characteristic nor isokinetic strength as a predisposing factor of patellofemoral pain. In addition, iliotibial band tightness in dancers has been shown to be a contributing factor to PFP possibly resulting in lateral patellar tracking.<sup>112</sup>

Extrinsic risk factors that may affect patellar tracking or increase forces placed on the patellofemoral joint include: type or use of equipment, training methods (excessive volume or hill training), training surfaces and external trauma to the patellofemoral joint.<sup>105</sup>

### 2.3 DEFINITIONS AND CLASSIFICATION OF PFP

PFP is usually described as diffuse, peripatellar, anterior knee pain.<sup>8,61</sup> Clinical features include pain, crepitation, stiffness and tightness, swelling, giving way and locking.<sup>68</sup> Symptoms are typically aggravated by activities such as stair ascending or descending, squatting, kneeling, running and prolonged sitting.<sup>8,68,73</sup> On examination, tenderness of the surrounding soft tissues including the medial and lateral retinaculum, patella, quadriceps tendons and fat pads may be present.<sup>111</sup>

There are six major anatomical structural sources of PFP: subchondral bone, synovium, retinaculum, skin, muscle, and nerve.<sup>34</sup> Two theories exist regarding the etiology of PFP. The first theory is of malalignment of the patella relative to the femoral trochlear resulting in abnormalities within the articular cartilage.<sup>44</sup> However, there is a poor correlation between articular cartilage lesions and pain<sup>27</sup> therefore, not all PFP can be attributed to this etiology. The most recent theory is that patellofemoral problems are the result of excessive mechanical loading and chemical irritation of the nerve endings.<sup>28</sup> In other words, the most common reasons for anterior knee pain are patellofemoral malalignment, overuse and trauma. Other uncommon aetiologies of knee pain include: traumatic prepatellar neuroma,<sup>53</sup> osteochondritis dissecans of the patellofemoral joint,<sup>80</sup> saphenous nerve entrapment, intraosseous hyperpressure of the patella, infra-patellar contracture syndrome, conditions affecting the deep infra-patellar bursa and fat pad, Sinding-Larson Johansen disease, bony cysts or abscesses and isolated ganglions of the anterior cruciate ligament.<sup>67</sup>

In the literature, there appears to be no consensus in the classification or management of patellofemoral conditions, possibly as a result of the many subtle variations of PFP. Hence, a wide variety of disorders may all fall under the 'umbrella' term of PFP. Patients presenting with different patellofemoral conditions often complain of similar symptoms which have led to the indiscriminate use of the term chondromalacia (patellofemoral chondrosis), which is not always associated with patients presenting with PFP.<sup>51</sup> Accurate diagnosis is important for the design of an optimal rehabilitation programme.<sup>34</sup> Classification systems help to divide patellofemoral disorders into various groups: 1) patellofemoral compression syndromes, 2) patellar instability, 3) biomechanical dysfunction, 4) direct patella trauma, 5) soft tissue lesions, 6) overuse syndromes, 7) osteochondritis diseases, 8) neurologic disorders.<sup>110</sup> Broader classification systems also exist: 1) patellofemoral instability, 2) PFP with malalignment, 3) PFP without malalignment.<sup>51</sup>

## **2.4 MANAGEMENT OF PFPS**

As a result of the complex causes of PFP disorders, a thorough systematic evaluation of the patient's lower extremity alignment, patellar mobility, muscle flexibility, strength, coordination, soft tissue and articular pain is important in prescribing an optimal rehabilitation programme. Management of patellofemoral pain syndrome (PFPS) often includes: reduction of pain and inflammation, cryotherapy, heat therapy, massage therapy, acupuncture, laser, patellar mobilisation, muscle flexibility and strength training

(especially quadriceps), taping, bracing, orthotics, correction of abnormal biomechanics or other causative factors, and surgery.<sup>8,18,34,73,81</sup> A systematic review of physical interventions for patellofemoral pain included in controlled trials with adequately described outcome assessments, revealed that significant reduction in PFPS symptoms were found with a corrective foot orthosis and a progressive resistance brace.<sup>18</sup> However, there was limited evidence to support the use of patellofemoral orthoses, acupuncture, low-level laser, chiropractic patellar mobilization or patellar taping.<sup>18</sup> Physiotherapy interventions including: quadriceps strengthening exercises, muscle stretching exercises, patellar mobilisation and patellar taping, produced consistent improvement in short-term pain and function in a placebo controlled trial.<sup>19</sup> However, these interventions, with the exception of the quadriceps strengthening exercises, were not isolated, therefore their individual efficacy is questionable.<sup>18,19</sup> Many of these techniques used by clinicians in the treatment of PFP have not been well defined through research and lack evidence of clinical efficacy.<sup>69</sup>

There appears to be no consensus in the literature regarding which type of exercise is most beneficial in rehabilitation. Some literature has advocated the importance of selective activation of the VMO during strengthening exercises.<sup>8,49,73,74</sup> However, several studies have demonstrated an inability to activate this muscle selectively during various exercises.<sup>11,57,62</sup> Adduction of the hip shows overflow to the VMO<sup>49</sup> which is not sufficient to provide a strong training level stimulus (greater than 70% maximum voluntary contraction) to the VMO, but may be effective in training motor control of the VMO. Further studies are required to validate this suggestion. Exercise interventions are

often targeted at training motor control rather than strength and endurance.<sup>19</sup> In addition, the ratio of VMO to VL activity has been shown to be no different between PFP subjects and the normal population.<sup>7,10,11,62,82,86,96,98,101,104</sup> Hence, focussing a rehabilitation programme on this presumed discrepancy may not be effective. Generalised quadriceps strengthening and stretching programmes have shown to be effective in the treatment of PFP syndrome.<sup>2,12,26,60,103</sup> Two of these studies were randomised controlled clinical trials.<sup>12,26</sup> Further trial lacked controls or randomization, therefore the evidence needs to be viewed with caution.

EMG biofeedback is a training procedure that has been used during quadriceps exercises in an attempt to equalise VMO and VL muscle activity. However, a randomised, controlled, clinical trial revealed that EMG biofeedback did not result in further clinical improvement when compared with an exercise programme in patients with PFP.<sup>26</sup>

In summary, a review of the literature reveals that physiotherapy interventions including: quadriceps strengthening exercises, muscle stretching exercises, patellar mobilisation and patellar taping may be effective in the treatment of PFP. Many other techniques used by clinicians in the treatment of PFP have not been well defined through research and lack evidence of clinical efficacy.<sup>69</sup>

## 2.5 PATELLAR TAPING

The proposed aim of patellar taping was to improve patellar tracking by mechanically realigning the patella medially, thus centralising the patella within the trochlear groove, thus affecting the function and activation of the quadriceps muscles.<sup>73</sup> Theoretically, patellar taping may either enhance the magnitude of activation and or timing of VMO relative to the VL muscles, or decrease the activation and or timing of the VL relative to the VMO.

### 2.5.1 Application

Patellar taping in the treatment of PFP as used by McConnell,<sup>73</sup> involves application of tape with a glide, tilt and or rotation component over the patella dependent on the assessment of the patellar orientation. Subsequent studies have shown the reliability of the McConnell classification system for the assessment of patellar orientation or patellar position, to be poor.<sup>85,109</sup> A further proposal, in the technique of tape application, is that the tape be applied to achieve pain relief independent of the initial patellar position.<sup>30</sup> Medial patellar tape compared to lateral patellar tape or neutral tape, has been shown to be most effective in pain relief in subjects with osteoarthritis.<sup>20</sup> Patellar taping in the treatment of PFP is most commonly applied directly over the patella with a force to pull the patella into a medial position.<sup>73</sup> Many hypotheses for the mechanism of action of the patellar tape have been proposed.

## 2.5.2 The Effect of Taping

### 2.5.2.1 *Pain*

Inhibition of pain is a possible mechanism by which patellar taping exerts its effect on the knee. Taping may unload the inflamed peri-articular synovium and soft tissue by moving it away from further mechanical irritation during functional movement, thus reducing pain.<sup>29,30</sup> In addition, tape may stimulate cutaneous sensory afferent stimulation, which overrides the pain signals received by the brain, thus reducing the perception of pain as described by the gate control theory of pain.<sup>75</sup>

The use of patellar taping reduced perceived pain levels in PFP subjects in several studies.<sup>3,6,11,13,18,19,20,37,40,46,47,48,73,74,84,94</sup> However, with the exception of three studies,<sup>3,20,46</sup> significant errors in study design may have resulted in bias or type 1 error. Firstly, most study designs were limited by the lack of randomisation of tasks performed with and without tape, lack of control subjects and lack of placebo tape.<sup>6,11,13,18,40,47,48,73,74,84,94</sup> Secondly, other studies required a 50% reduction in pain after taping (using a variety of taping techniques) and prior to testing, thus preselecting subjects, in whom tape would reduce pain.<sup>6,11,40,84,94</sup> Thirdly, treatment modalities, in addition to tape, were used in some of these uncontrolled clinical trials.<sup>19,37,73</sup> Pain was reduced in PFP subjects after a programme of rehabilitation exercises whether tape was applied or not, suggesting no additional benefit of adding taping to rehabilitation exercises in the treatment of patellofemoral pain.<sup>12,60</sup> However, a recent randomized controlled clinical trial has found patella tape effective in pain reduction.<sup>116</sup>

### 2.5.2.2 *Strength*

Stokes and Young<sup>100</sup> have described a reflex inhibition of the quadriceps with ensuing weakness after trauma to the patellofemoral joint. Therefore, a further hypothesis for the possible mechanism of action of the tape, is that it may reduce this reflex inhibition of the quadriceps by inhibiting pain, with a resultant increase in quadriceps peak torque. Taping has been shown to increase quadriceps torque by 7% to 26%,<sup>13,46,47</sup> increase the knee extensor moment by 16% to 150%,<sup>32,94</sup> and power by 27% in PFP subjects.<sup>32</sup> However, with exception of the kinematic study by Ernst et al<sup>32</sup> and the isokinetic study by Handfield and Kramer,<sup>46</sup> the other studies were limited by the lack of randomisation and placebo control. A rehabilitation programme produced a 50% increase in strength in PFP subjects with and without the use of tape,<sup>60</sup> suggesting that there may be no additional benefit of adding tape to a rehabilitation programme aimed at improving quadriceps strength deficits. However further studies need to be done to support this finding.

### 2.5.2.3 *EMG Activity*

There appear to be some discrepancies in the literature when comparing VMO and VL EMG activity between PFP and control subjects.<sup>41,70,78,82,86,104</sup> However, many authors show no difference in VMO EMG activity between PFP and control subjects<sup>7,10,62,104</sup> It is useful to compare the activity of VMO relative to VL in order to detect any imbalance in quadriceps activity. The literature suggests that there is also no significant difference in VMO/VL ratio between PFP and control subjects.<sup>7,10,11,62,82,86,96,98,101,104</sup>

In asymptomatic subjects, coactivation of VMO and VL has most commonly been reported.<sup>15,16,58,78,82,96,107,113</sup> Coactivation implies no significant difference in the time of onset of VMO relative to VL. Many studies have shown no difference between PFP subjects and control subjects regarding onset of activation of VMO and VL<sup>58,78,82</sup> and the onset of peak activation of VMO and VL.<sup>96</sup> However, some studies have reported a delay in the activation of VMO in PFP subjects during functional tests.<sup>15,16</sup>

Theoretically, patellar taping may result in altered quadriceps muscle recruitment. Although the precise mechanism is unclear, researchers have demonstrated that cutaneous stimulation alters the recruitment threshold and recruitment order of motor units.<sup>36,54</sup> McConnell<sup>73</sup> initially proposed that tape enhances VMO activity based on a trial which lacked placebo, randomisation and control subjects, and which has not been supported by subsequent studies.<sup>11,48,60,94</sup>

However, a single study has shown earlier VMO activation during step up and step down tests after taping.<sup>40</sup> It is still unclear if earlier activation of the VMO improves patellar tracking or alignment, or if in fact earlier activation of the VMO occurs in normal healthy knees.

#### 2.5.2.4 *Patellar Position and Proprioception*

There has been an assumption that patellar tape improves patellar tracking by repositioning the patella within the trochlear groove, with resultant decreased load on the patellofemoral joint.<sup>17,73</sup> However, many radiological studies have shown no change in

patellar position at rest,<sup>6,39</sup> or no sustained change in patellar position with tape compared to no tape, during exercise.<sup>63</sup>

It has been shown that the brain's assessment of joint position may be determined by afferent input from skin strain patterns from tape.<sup>31</sup> This skin sensory input to the brain may have precedence over muscle afferent input and be perceived as joint movements rather than skin deformation.<sup>31</sup> In other words, the brain may perceive that the tape has produced a change in position of the patella in the femoral trochlear via the information received from the skin strain pattern produced by the tape. As proprioception may be less accurate and less consistent in PFP subjects,<sup>4</sup> taping may enhance proprioceptive input to the brain.

#### 2.5.2.5 *Gait*

Differences in gait strategies have been found when comparing PFP subjects with the normal population. Compensatory gait strategies including decreased knee flexion,<sup>23</sup> reduced walking velocity,<sup>83</sup> reduced vastii muscle activity,<sup>82</sup> and decreased knee extensor moments,<sup>93</sup> have been found in PFP subjects. These compensatory gait strategies may suggest that in order to reduce patellofemoral joint reaction forces, 'quadriceps avoidance' is employed.

Taping has been shown to alter these compensatory gait strategies by increasing step cadence and knee extensor moments,<sup>94</sup> increasing stride length,<sup>84</sup> and increasing the knee flexion angle in response to loading.<sup>84,94</sup> It is suggested that taping may result in an

increased confidence in the subject to load the knee joint thus restoring full function of the knee joint.<sup>84</sup> However, there is no evidence to support this comment. As quadriceps EMG activity increases with increasing knee flexion between 0° and 90°,<sup>5,9,101</sup> increased knee joint flexion during walking, after patellar taping, may produce increased quadriceps activity and enhance strength rehabilitation.

#### 2.5.2.6 *Placebo*

The positive effect of patellar taping may be explained by the placebo effect. Few studies have included placebo taping in addition to corrective taping. However, studies conducted using placebo tape show favourable results with medial patellar taping compared to the placebo tape.<sup>3,20,32,46</sup> This implies that a treatment intervention and or cutaneous stimulation from the presence of tape on the skin, may not be the mechanism of action of medial patellar tape. Medial patellar tape is different to the placebo tape in that it exerts a more severe skin strain pattern that may result in a different, possibly enhanced, afferent input to the brain with resultant changes in pain, strength or neuromuscular recruitment.

## 2.6 CONCLUSION

Patellofemoral disorders are amongst the most common clinical conditions encountered in the sporting and general population resulting in disability with regard to activities of daily living and sports participation. Therefore, it is paramount that a clinician's

knowledge and understanding of the patellofemoral joint mechanics, predisposing factors to PFP and the efficacy of treatment modalities currently used, is optimal in order to determine the most effective treatment options for this condition.

Factors associated with PFP and the management of this condition with particular reference to the patellar tape has been reviewed. The literature reveals that physiotherapy interventions including: quadriceps strengthening exercises, muscle stretching exercises, patellar mobilisation and patellar taping may be effective in the treatment of PFP. Many other techniques used by clinicians in the treatment of PFP have not been well defined through research and lack evidence of clinical efficacy.<sup>69</sup>

The literature is unclear on the effect of tape on pain, strength, EMG activity, patellar position, proprioception and gait as well as the placebo effect of tape. Various mechanisms of action of the tape have been proposed.

However, further placebo controlled clinical trials are necessary to clarify the effects of tape on the patellofemoral joint and to identify the mechanisms by which various taping procedures influence patellofemoral joint mechanics.

## CHAPTER 3

### RESEARCH PAPER

#### THE EFFECT OF MEDIAL PATELLAR TAPING ON PAIN, STRENGTH AND NEUROMUSCULAR RECRUITMENT IN SUBJECTS WITH AND WITHOUT PATELLOFEMORAL PAIN

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## 3.1 ABSTRACT

### 3.1.1 Title

The effect of medial patellar taping on pain, strength and neuromuscular recruitment in subjects with and without patellofemoral pain.

### 3.1.2 Study Design

A randomised, controlled, clinical trial.

### 3.1.3 Objectives

To examine any differences in strength and neuromuscular recruitment between subjects with patellofemoral pain (PFP) and subjects without PFP. Secondly, to examine the effect of medial patellar taping on pain, strength and neuromuscular recruitment (quantity and time of onset of EMG activity) during open chain and closed chain exercises in subjects with and without PFP.

### 3.1.4 Background

Patellar taping is used by clinicians in an attempt to reduce pain, increase strength, enhance neuromuscular recruitment and correct the time of onset of activation of vastus medialis oblique (VMO) relative to vastus lateralis (VL). However, the evidence supporting the efficacy of patellar taping is not clear with studies showing varied responses.

### 3.1.5 Methods and Measures

Fifteen subjects with PFP (experimental group) and twenty subjects without PFP (control group) performed maximal isometric, concentric and eccentric quadriceps strength tests as well as functional step up and step down tests. The tests were administered under three different knee conditions (no tape, placebo tape and medial tape) in randomised order. Peak and mean quadriceps force output as well as EMG activity (quantity of EMG and time of onset of EMG) from the VMO and VL was measured and pain was scored using a 10 cm visual analogue scale. An analysis of variance (ANOVA) with repeated measures was used to determine differences between the main effects (group and taping conditions) and interaction effects (group  $\times$  taping conditions). When the overall F value was significant, a Tukey post hoc test was performed.

### 3.1.6 Results

The PFP group, compared to the control group, experienced significantly ( $p < 0.05$ ) more pain with testing, produced 21 % less quadriceps force during all tests, produced less force/EMG (muscle efficiency) during most tests, produced 29 % greater VMO EMG activity during the step tests, and produced no difference in time of onset of VMO relative to VL during the isokinetic and step tests, with delayed onset of activation of VMO relative to VL during the isometric strength test. There were no significant differences in VL EMG activity or VMO/VL ratio between the PFP and the control groups with no tape.

Medial patellar tape as used in this study, did not result in a significant reduction in pain, an increase in quadriceps force output or a change in the time of onset of activation of VMO relative to VL in the PFP group. However, tape did produce a 17 % decrease in VMO EMG activity and a decrease in VMO/VL ratio during the step tests in both the PFP and control groups ( $p < 0.05$ ).

### 3.1.7 Conclusion

These results show differences between the PFP and control subjects with respect to pain, quadriceps force output and neuromuscular recruitment. Medial patellar tape as used in this study, produced an effect on the neuromechanics of the patella, but possibly not the proposed effects initially suggested. It is not clear if these effects would have any clinical benefit in individuals with PFP.

### 3.1.8 Keywords

Knee; Patellofemoral pain; Patellar taping; Muscles; VMO; Force output; Electromyography.

### 3.2 INTRODUCTION

Patellofemoral disorders are amongst the most common clinical conditions encountered in the sporting and general population.<sup>8,33,68</sup> Patellofemoral pain (PFP) is usually described as diffuse, peripatellar, anterior knee pain.<sup>8,61</sup> Symptoms are typically aggravated by activities such as stair ascending or descending, squatting, kneeling, running and prolonged sitting.<sup>8,68,73</sup> The most common reasons for the development of anterior knee pain are patellofemoral malalignment, overuse and trauma. Factors predisposing a person to PFP include abnormal biomechanics, soft tissue tightness, muscle dysfunction and training errors.<sup>8</sup>

A wide variety of disorders may fall under the 'umbrella' term of PFP. As a result, a thorough systematic evaluation of the patient's lower extremity alignment, patellar mobility, muscle flexibility, strength, coordination, soft tissue and articular pain is important in determining the causes of PFP and prescribing an optimal rehabilitation programme. Management of patellofemoral pain syndrome (PFPS) often includes reduction of pain and inflammation through cryotherapy, heat therapy, massage therapy muscle flexibility and strength training (especially quadriceps), patellar taping, bracing, orthotics, correction of abnormal biomechanics or other causative factors, acupuncture, and surgery.

Patellar taping is used by clinicians during the treatment of PFP, in an attempt to reduce pain, increase strength and enhance neuromuscular recruitment and correct timing of

onset of activation of vastus medialis oblique (VMO) relative to the vastus lateralis (VL). Patellar taping in the treatment of PFP is most commonly applied directly over the patella with a force to pull the patella into a medial position.<sup>73</sup> Many hypotheses for the mechanism of action of the patellar tape have been proposed and include: 1) pain inhibition, 2) reduction of reflex inhibition of the quadriceps with a resultant increase in peak torque, 3) altered quadriceps muscle recruitment, 4) improved patellar tracking by repositioning the patella within the trochlear groove with resultant decreased load on the patellofemoral joint, 5) alteration of compensatory gait strategies, 6) enhanced proprioception, and 7) the placebo effect of a clinical intervention.<sup>4,6,29,31,36,54,63,73,75,84,100</sup>

The aim of this study is firstly, to investigate the possible differences in strength and neuromuscular recruitment between subjects with PFP and subjects without PFP. Secondly, to investigate the effect of medial patellar taping on pain, strength and neuromuscular recruitment (quantity and time of onset of EMG activity) during open chain and closed chain exercises in subjects with and without patellofemoral pain.

### 3.3 METHODOLOGY

#### 3.3.1 Experimental Design

The study design is a randomised, controlled clinical trial of three different knee treatment conditions: with medial patellar tape, with placebo tape and no tape.

#### 3.3.2 Subject Characteristics

Subjects were recruited from the Sport Science Institute South Africa, as well as physiotherapy and medical practices within Cape Town, South Africa. The experimental group consisted of 15 subjects with PFP, and the control group consisted of 20 subjects without PFP. These two groups were matched in age, fitness, gender and anthropometrical data. All subjects were less than 40 years of age to reduce the likelihood of subjects presenting with osteoarthritic changes in the patellofemoral joint. The testing procedure for the two groups was identical. Each subject performed all the tests, with each of the three knee treatment conditions, in randomised order.

In order to fulfill the inclusion requirements of this study, the PFP subjects were required to present with retropatellar or peripatellar pain with insidious onset, of at least 5 weeks duration. In addition, the subjects had a minimum of 3 of the following 5 criteria:<sup>37,73</sup>

1. Retropatellar/peripatellar pain on physical examination of the patella.
2. Pseudolocking: clicking and a painful or painless “catching”.
3. Pain on walking up or down stairs.
4. Pain or stiffness on prolonged sitting.

## 5. Pain on squatting.

Exclusion criterion for subjects in both groups were: a history of traumatic knee injury including knee ligament or cartilage injury, patellar subluxation or dislocation, prior knee surgery, other musculo-skeletal injury to either lower extremity, or any history of allergy to tape or concerns regarding a tape allergy.

The PFP subject's grade of injury was measured on a scale of 1 to 4. A grade 1 injury was defined as knee pain after sport but not during sport, a grade 2 injury as knee pain during but not affecting sport, a grade 3 injury as knee pain during and affecting sport, and a grade 4 injury as pain preventing sport's participation.<sup>64</sup> Prior to the onset of symptoms, subjects were required to have participated in a minimum of 2 hours of sport per week. Subjects were able to participate in sport after the onset of symptoms even though the pain may have affected their sporting activity (Grade 2 or 3 injury).

On arrival at the laboratory, all subjects had the tests fully explained to them and signed an informed consent in their preferred language: English (Appendix 1), isiXhosa (Appendix 2), or Afrikaans (Appendix 3). Subjects completed the Medical and Sporting History Questionnaire (Appendix 4) which evaluated the above-mentioned criterion and suitability for participation in this study. The study was approved by the Ethics and Research Committee of the University of Cape Town.

### 3.3.3 Anthropometrical Evaluation

Anthropometrical data were collected on all subjects (Appendix 5). Height, age, mass, skinfolds (biceps, triceps, sub-scapular, supra-iliac, abdominal, calf and thigh), girth (sub-gluteal, mid-thigh, above knee, calf and forearm) and length measures (sub-gluteal to above knee) were recorded. The lean thigh volume, percentage body fat and muscle mass were calculated. Lean thigh volume was calculated using the assumption that the thigh was the shape of a truncated cone.<sup>59</sup> Body fat was expressed as both the sum of seven skinfolds and as a percentage, based on calculations of Durnin and Womersley.<sup>25</sup> The afore-mentioned girth and length measures were used to calculate muscle mass.<sup>71</sup>

### 3.3.4 Taping Technique and Application

The patellar tape with the medial glide component,<sup>73</sup> was used in this study. The McConnell patellar taping technique firstly involves assessment of patellar position. Secondly tape is applied in order to correct any patellar malalignment found on assessment. However, the McConnell classification system of patellar orientation has not been proven reliable.<sup>85,109</sup> Therefore, the taping technique used in this study, was standardised to the most frequently used taping, McConnell's medial patellar taping, for all subjects. This technique makes use of flexible Fixomull, hypoallergenic tape under the rigid leucotape (Ref no 2036; Manufacturer: BSN Medical, GMBH & co. KG, D-22771, Hamburg, Germany; local supplier: Lawo Africa P.O. Box 90, Noordhoek, 7985, South Africa). The placebo patella tape was the Fixomull tape alone, and was applied directly over the patella as above without any medial glide. The tape was applied by a qualified physiotherapist, experienced in the McConnell technique. The order of tape application

was randomised with each subject being assigned to one of 6 different testing combinations of the 3 tape applications. Subjects could feel if they had tape applied to their knee or not, therefore, blinding the subjects to tape application was impossible. However, the differences between the two taping conditions (placebo and medial patellar tape) was not explained to the subjects. No allergies to taping occurred within either the experimental or control groups.

### 3.3.5 Isokinetic Evaluation

The KinCom Isokinetic Dynamometer (Chattanooga Group, Inc., Chattanooga, USA) was used to test the muscle strength of the quadriceps during maximal isokinetic (concentric and eccentric) and isometric tests, whilst EMG data were recorded (Appendix 6). The subjects were seated with the hip in 90° flexion and were stabilised in the chair with a strap across the chest and waist. Subjects were advised to keep their arms folded across the chest to prevent use of the upper body during leg extension. Isokinetic tests were performed with the knee extending or flexing between 85° and 5°. Isokinetic testing velocities of 120° per second were chosen in this study, so as not to cause undue exacerbation of pain. Previous isokinetic studies have produced higher pain scores at lower testing velocities (60°/s) and lower pain scores at higher testing velocities (180°/s).<sup>46,47</sup> This test was followed by the isometric tests, which were performed in 60° of knee flexion. Subjects were advised to push as fast and as hard as they were able to when instructed.

All subjects were familiarised with the equipment and testing procedure prior to the start of data collection. Subjects were asked to perform 10 sub-maximal concentric contractions and eccentric actions of the quadriceps, gradually progressing from 50% to 90% of their maximum, as part of the warm up. Thereafter, 3 maximal concentric contractions and eccentric actions of the quadriceps were performed. The concentric and eccentric actions producing the greatest peak quadriceps force output were recorded for analysis. This test was followed by a warm up of 5 sub-maximal isometric actions of the quadriceps with a 5 second hold and 5 second rest period between each action. This was followed by 3 maximal isometric voluntary contractions (MIVC) of the quadriceps. The isometric action producing the greatest peak force output was recorded for analysis. Verbal encouragement was given consistently throughout testing by the same tester. The subjects were given the manual switch and advised how to switch off the machine should pain escalate during testing. In addition, crushed ice was available in the event of pain escalation with testing. However, neither the manual switch nor ice was needed by any of the subjects. The entire testing procedure took approximately 70 minutes per subject.

### 3.3.6 Functional Evaluation

The functional test consisted of a step up, immediately followed by a step down with the same leg on the step for both the step up and step down. This step test was performed over a gym step bench of 20 cm in height while simultaneous EMG data were recorded. This test was performed to a recorded voice counting 3 seconds for the step up and 3 seconds for the step down. This test was repeated 3 times. EMG onset was detected as the burst of activity as the subject's foot makes contact with the step. EMG amplitude

was measured over a 0.5 second period during the greatest burst of EMG activity. EMG values for this test were averaged. All testing was performed without shoes (bare foot) to prevent the confounding effect of differences in shoe type.

### 3.3.7 Electromyographic Evaluation

Electromyographic (EMG) data from the bellies of VMO and VL muscle, were collected during isokinetic, isometric and functional testing. The subject's skin was prepared by shaving off the hair and outer layer of epidermal cells and then cleaned with alcohol swabs. A surface Triode EMG electrode (Thought Technology Triode™ MIEP01-00, Montreal, Canada) was placed over the mid point of the bellies of the VMO and VL and orientated in line with the longitudinal fibres.<sup>16,40,78</sup> The VMO electrode was placed approximately 4 cm superior to and 3 cm medial to the supero-medial patella border and orientated 55° to the long axis of the patella. The VL electrode was placed approximately 10-15 cm superior to and 6 cm lateral to the superior border of the patella, orientated 15° to the long axis of the patella. The quadriceps muscles were isometrically contracted prior to electrode placement to identify the midpoint of the muscle belly. The electrode was not moved during testing and was linked to an amplifier box which was connected via a fibre optic cable to the computer with Flexcomp/DSP software (Thought Technology, Montreal Canada), for recording of data.

EMG readings were sampled at 1984 Hz and were passed through a 50 Hz line filter to remove interference from electrical sources to yield raw data. Movement artefact was removed from these raw signals with a high-pass second order Butterworth filter with a

cut off frequency of 20 Hz. The means of the EMG signals were then removed and the signals were full-wave rectified. The signals were then smoothed with a linear envelope using a low-pass second order Butterworth filter with a cut-off frequency of 10 Hz. Filtering procedures were performed using MATLAB<sup>TM</sup> software (The MathWorks Inc. Natick, MA, USA). The raw EMG data was processed to yield amplitude and frequency compression data using software courtesy of H Mullany (University College Dublin, 2000).

EMG amplitude was calculated using the root mean square method. The mathematical procedures to accomplish the integration of the EMG signal are: root mean square (rms) conversion, averaging of the signal and real integration. Integrated EMG has shown to be a reliable method to study strength qualities of muscle during maximal and submaximal contractions.<sup>115</sup>

The normalisation of the data were performed by expressing each subject's EMG data as a percentage of the isometric EMG data obtained whilst the subject performed the maximal isometric strength test with no tape applied. This EMG normalisation process, as opposed to working with raw EMG data, negates the potentially confounding effects of differences in lean muscle mass and percent body fat between subjects and the individual variation introduced as a result of electrode placement.

The relative time of onset of activation of EMG activity in the VMO and VL muscles, was recorded for the concentric, eccentric, isometric and step tests and assessed visually

by the tester, on 3 separate occasions. The data from the first of these 3 occasions were used for the data analysis. Methods for determination of the onset of EMG activity also vary, however the visual determination of EMG onset, as used in this study, has proven to be highly accurate when compared to a range of computer-based techniques.<sup>50</sup> In addition, within a normal population, a difference of greater than 12.20 ms in the concentric and 11.56 ms in the eccentric phase of stair stepping would be required to demonstrate a significant difference in EMG onsets of VMO and VL between groups.<sup>14</sup>

The time of onset of VMO relative to VL EMG activity was expressed as the difference between the VMO and VL [VMO – VL, measure in milliseconds (ms)]: a positive result indicating earlier activation of VL relative to VMO.

### 3.3.8 Pain Evaluation

A 10 cm Visual Analogue Scale (VAS) was used after each test to record the subjects perceived pain.<sup>76</sup> (Appendix 7). The VAS has proven to be a reliable method of testing pain.<sup>77</sup>

### 3.3.9 Statistical Analysis

Appropriate statistical tests were performed on the data using the Statistica 6.1 software package (StatSoft Inc, Tulsa, OK, USA). The independent T-test was used to determine any significant differences between PFP subjects and control subjects for descriptive characteristics. An analysis of variance (ANOVA) with repeated measures was used to determine differences between the main effects (group and taping conditions) and

interaction effects (group  $\times$  taping conditions). When the overall F value was significant, a Tukey post hoc test was performed. When there was a significant interaction effect, a one way analysis of variance was used to determine the specific differences. All data were expressed as mean  $\pm$  standard deviation (SD). Statistical significance was accepted when  $p < 0.05$ .

A pilot study was performed in order to determine tester reliability in the visual assessment of time of onset of activation of VMO and VL EMG activity. Time of onset data were collected from the initial EMG activity recordings of 5 randomly selected subjects, for all the tests, on 3 separate occasions, for test-retest reliability analysis. An analysis of variance (ANOVA) with repeated measures was used to determine whether there were differences between tests. When the overall F value was significant, a Tukey post hoc test was performed. Statistical significance was accepted when  $p < 0.05$ .

## **3.4 RESULTS**

### **3.4.1 Subject Characteristics**

Anthropometrical data for the control and patellofemoral pain (PFP) groups showed no significant differences (Table 1). The control group included 7 males and 13 females, aged 21 to 38 years (mean  $29.4 \pm 4.6$  years). Seven left and 14 right knees were tested, in order to match the ratio of left to right knees tested in the PFP group. The PFP group included 4 males and 11 females, aged 18 to 36 years (mean  $29.1 \pm 5.1$  years). Five left

and 10 right knees were tested, according to the most symptomatic knee presented. The ratio of left to right knees tested was 0.33 in both groups. There were no significant differences in sport's participation, measured in hours per week, between the control ( $5.3 \pm 3.2$  hours) and PFP ( $5.1 \pm 3.6$  hours) group. Within the PFP group, the grade of injury was  $2.3 \pm 0.5$  and the mean pain duration was  $124 \pm 196$  weeks (ranging from 5 to 624 weeks)

#### 3.4.2 Pain

Pain scores were significantly greater in the PFP compared to the control group during all the tests (MIVC, concentric/eccentric and step;  $p < 0.05$ ) with no tape, placebo and tape. In the PFP group, no significant differences were found in pain scores between the no tape, placebo and tape conditions during all the tests (Figure 1, Table 2).

#### 3.4.3 Strength

Quadriceps peak force was 19 % less in the PFP group compared to the control group, during the MIVC and concentric tests ( $p < 0.05$ ) with no tape, placebo and tape (Figure 2, Table 3). There was no significant difference in quadriceps peak force between the PFP and the control group during the eccentric test with no tape, placebo and tape (Figure 2, Table 3). Quadriceps mean force was 21 % less in the PFP group compared to the control group during the MIVC, concentric and eccentric tests ( $p < 0.05$ ) with no tape, placebo and tape. No treatment difference or interaction between treatment  $\times$  group was found. Taping brought about no significant difference in force production within the PFP group or the control group during MIVC, concentric and eccentric tests (Figure 3, Table 3).

### 3.4.4 EMG Activity

#### 3.4.4.1 *EMG Quantity*

VMO EMG activity between or within the PFP and control group during MIVC, concentric and eccentric testing produced no significant differences (Table 3). However, the VMO EMG activity was 30 % greater during the step up test and 27 % greater during the step down test ( $p < 0.05$ ) in the PFP compared to the control group, with no tape, placebo and tape (Figure 4, Table 3). In addition, VMO EMG activity was 19 % less during the step up with tape and 14 % less during the step down with tape compared to the no tape and placebo conditions, in both the PFP and the control group (Figure 5, Table 3).

There were no significant differences in the VL EMG activity between the control and PFP group during all tests and in all taping conditions (Figure 6, Table 3).

#### 3.4.4.2 *Force/EMG*

Expressing force per normalised EMG value is used to determine the amount of force produced by a certain portion of the recruited muscle. Peak Force/EMG values for the VMO were significantly less in the PFP than the control group during the concentric and eccentric tests ( $p < 0.05$ ) with no tape, placebo and tape (Table 3), however, no significant differences were found between groups during the MIVC test. Peak force per EMG values for the VMO were significantly greater with tape ( $p < 0.05$ ) compared to placebo in both the PFP and the control group. Peak Force/EMG values for the VL were significantly less in the PFP than the control group during the MIVC and eccentric tests

( $p < 0.05$ ) with no tape, placebo and tape (Table 3). However, no significant differences were found between groups during the concentric test.

#### 3.4.4.3 *VMO/VL*

The VMO/VL ratio is useful to compare the activity of VMO relative to VL in order to detect any imbalance between the two muscles of the quadriceps. There were no significant differences in the VMO/VL ratio between the control and the PFP group, except during the MIVC test, where a significant interaction between treatment  $\times$  group was found ( $p < 0.05$ ). The PFP group had a significantly greater VMO/VL ratio than control group, when comparing the placebo MIVC tests ( $p < 0.05$ ) (Figure 7, Table 3). Both the control and PFP group showed significantly lower VMO/VL ratios during the step up and step down tests with tape ( $p < 0.05$ ), than no tape and placebo (Figure 8, Table 3).

When comparing the VMO/VL ratio during the closed chain tests (step) with all the open chain tests (MIVC, concentric, eccentric), both the PFP and control groups showed significantly greater VMO/VL ratios during the step tests than the open chain tests ( $p < 0.05$ ) with no tape and placebo. However, no significant difference was found between the step and all the open chain tests in both groups with tape.

#### 3.4.4.4 *Time of Onset of VMO and VL*

Visual determination of time of onset of activation of VMO relative to VL, expressed as the difference between VMO and VL time of onset EMG activity, was not significantly

different for all three trials, during the MIVC test with no tape and tape, the concentric test with no tape, placebo and tape, the eccentric test with placebo and tape, and the step test with no tape, placebo and tape (Table 4). A significant difference in the determination of the onset of VMO and VL was recorded during the eccentric test with no tape ( $p < 0.05$ , with the first set of data recorded being significantly different to the second and third set of data) and during the MIVC test with placebo ( $p < 0.05$ , with the first set of data recorded being significantly different from the second set of data) (Table 4). Therefore, the data from the eccentric test with no tape and the MIVC test with placebo, have been excluded from this study as a result of the data being unreliable.

The onset of activation of VMO relative to VL was delayed by 3.4 times in the PFP group compared with the control group during MIVC test ( $p < 0.05$ ) with no tape, placebo and tape (Figure 9, Table 5). However, the data from the MIVC test with placebo is deemed unreliable. No treatment differences or interaction between treatment  $\times$  group was found. The difference between the mean time of VMO onset of activation and the mean time of VL onset of activation was positive during most tests, with the exception of the PFP eccentric test with no tape, the PFP step up test with tape and control step up test with no tape (Table 5). When the difference between VMO and VL onset times is positive, this indicates that VL was activated prior to VMO. No significant difference was found in the order of activation of VMO and VL, between or within the control and PFP group according to the different taping conditions.

### 3.5 DISCUSSION

The main findings of this study are that the PFP group compared to the control group demonstrated: 1) increased pain with all tests, 2) decreased quadriceps force output, 3) decreased muscle efficiency (force/EMG) during most tests, 4) increased VMO activity during the step test and 5) no difference in onset of activation of VMO relative to VL during the open and closed chain tests, except during the isometric strength test where delayed onset of VMO relative to VL occurred in the PFP group. Medial patellar tape, as used in this study, does not produce a decrease in pain, an increase in strength and a change in the onset of activation of VMO relative to VL in the PFP group, as previously suggested. In addition, decreased VMO EMG activity and decreased VMO/VL ratio was evident during the step tests performed with tape in both the PFP and control groups.

This study is unique in that it includes both open chain testing (maximal isometric voluntary contraction, concentric and eccentric isokinetic torque) and functional closed chain testing. In addition, testing is performed on subjects with PFP as well as healthy control subjects. Furthermore, randomisation and placebo control, form part of this study design.

#### 3.5.1 Pain

Pain scores were significantly greater in the PFP compared to the control group during testing, in this study. Pain scores in PFP subjects were below 4.4/10 (mean values between 1/10 and 2.5/10 on the VAS) during testing. Other studies also demonstrated

low pain scores with testing (mean values between 1.5/10 and 4/10) yet reduction in pain with taping was still noted.<sup>6,48</sup>

Pain was not significantly different between the tape, placebo and no tape conditions, during all the tests, in the PFP group, in this study. This finding is in contrast to previous studies.<sup>3,6,11,13,18,19,37,40,46,47,48,73,74,84,94</sup> However, with the exception of three studies,<sup>3,20,46</sup> significant errors in study design may have resulted in bias or type 1 error. Firstly, most study designs were limited by the lack of randomisation of tasks performed with and without tape, lack of control subjects and lack of placebo tape.<sup>6,11,13,18,40,47,48,73,74,84,94</sup> Secondly, other studies required a 50% reduction in pain after taping (using a variety of taping techniques) and prior to testing, thus preselecting subjects, in whom tape would reduce pain.<sup>6,11,40,84,94</sup> The patellar tape with the medial glide component,<sup>73</sup> was used in this study which is different to the variety of techniques used in other studies. Thirdly, treatment modalities, in addition to tape, were used in some of these uncontrolled clinical trials.<sup>19,37,73</sup> The PFP subjects in this study were required to be participating in at least two hours of sport per week. Hence a fitter group of subjects in this study compared with other studies wherein all subjects were included irrespective of their sport's participation,<sup>3,6,11,13,18,19,37,40,46,47,48,73,74,84,94</sup> may have led to a different response to taping.

### 3.5.2 Strength

Previous studies have shown PFP subjects to have a reduced quadriceps torque,<sup>83,104</sup> and decreased explosive strength compared to control subjects.<sup>104,114</sup> In this study, the PFP group produced 21 % less mean quadriceps force than controls during the isometric,

concentric and eccentric tests. However, the peak quadriceps force output was 19 % less in the PFP group than the control group during the isometric and concentric tests, but not in the eccentric test. This maintenance of peak force output in the PFP group during the eccentric tests, may be due to the selection criterion of the PFP subjects in this study. That is, all subjects were required to be participating in at least two hours of sport per week. Maintenance of peak eccentric strength may have occurred as a result of their activity level.

Tape appears to have had no significant effect on force production in either the control or the PFP group. This is in contrast to previous studies that showed an increase in torque,<sup>13,46,47,73,74</sup> and an increase in knee extensor moment<sup>94</sup> and power<sup>32</sup> in PFP subjects with patellar tape. However, all these studies applied the tape according to the McConnell classification of patella orientation that allows for modification of the taping technique for each individual. Even though this classification system has been shown to be unreliable,<sup>85,109</sup> this individualised application of tape has produced an increase in strength in many studies.<sup>13,46,47,73,74</sup> However, subjects were included only if they experienced a 50% reduction in pain with tape thus introducing a type 1 error of selection bias into the study design. In addition, many studies lacked randomisation or placebo control in their study design.<sup>13,47,73,74,94</sup> This study used the McConnell tape with medial glide alone and all subjects were included whether they experienced pain relief with the tape, or not.

Stokes and Young<sup>100</sup> have described a reflex inhibition of the quadriceps with ensuing weakness after trauma to the patellofemoral joint. Therefore, a further hypothesis for the possible mechanism of action of the tape, is that it may reduce this reflex inhibition of the quadriceps by inhibiting pain, with a resultant increase in quadriceps peak torque. As pain relief did not occur with tape, it is not surprising that force output was not increased with tape. A rehabilitation programme produced an increase in strength in PFP subjects with and without the use of tape,<sup>60</sup> suggesting that there is no additional benefit of adding tape to a rehabilitation programme aimed at improving quadriceps strength deficits.

### 3.5.3 EMG Activity

#### 3.5.3.1 *EMG Quantity*

There appears to be some discrepancies in the literature when comparing VMO and VL EMG activity between PFP and control subjects. Increased VMO and VL activity during eccentric contraction,<sup>78</sup> and decreased activity in all vastus muscles (VL, VML, VMO) during functional activities has been reported in PFP subjects compared to control subjects.<sup>82</sup> PFP subjects with patellar subluxation have shown decreased VMO activity,<sup>70</sup> no significant differences in VMO activity,<sup>104</sup> and increased VMO activity the greater the lateral patellar displacement when compared to the normal population.<sup>86</sup> Most authors show no difference in VMO activity between PFP and control subjects.<sup>7,10,62,104</sup>

In this study, VMO EMG activity showed no significant differences between the PFP and control subjects during isometric and isokinetic (open chain) tests. However, during the step (closed chain) tests with no tape, placebo and tape, the PFP group produced 30 % and 27 % greater VMO EMG activity during the step up and step down tests respectively,

compared to the control group. It appears that this closed chain test required greater recruitment of VMO fibres in PFP subjects compared to control subjects. However, it is possible that pain experienced by PFP subjects during the MIVC test caused submaximal recruitment of VMO fibres, hence this 'maximal' test may have become a submaximal test for the PFP subjects. As the VMO activity during the step test was expressed as a percentage of the MIVC, these values may appear inflated.

There was no difference in VL EMG activity between the control and PFP group during any of the tests in this study. From the results of these tests, it appears that VL may not play a role in PFP. Either VL recruitment is not inhibited by pain, or this theory of pain inhibiting the quadriceps, turning the maximal test into a submaximal test, is invalid.

The literature does not appear to support the theory<sup>73</sup> that tape enhances VMO activity.<sup>11,48,60,94</sup> In accordance with the literature, this study showed no significant differences in VMO EMG activity within the PFP and control subjects during the open chain tests. However, during the closed chain (step) test, tape compared to no tape and placebo, appeared to produce an inhibitory effect on the VMO during the step up (by 19 %) and step down (by 14 %) tests in both control and PFP subjects. This means that fewer VMO fibres were recorded to be activated in order to perform the same task, hence the muscle appears to be working more efficiently. The open chain testing used maximal strength whereas the closed chain tests were submaximal. It is unknown if the action of this medial tape is different in maximal as opposed to submaximal tests. In addition, the open chain tests were performed in, or moved through, a range of knee flexion greater

than 40°, whereas the closed chain tests moved through a knee flexion range less than 40°. The patella has most medial and lateral mobility prior to engaging in the femoral trochlear groove at approximately 30°. <sup>24,87,95,97</sup> Therefore, the closed chain test may have allowed for a greater action of the tape on the patella due to increased patellar mobility at this range of knee flexion. The tape may play a stabilising role: it might improve the position of the patella, thus producing a greater mechanical advantage. However, this theory is not supported by radiological studies (X-ray and CT scans) where no change in patella position from pre to post McConnell taping was found, <sup>6,39</sup> and no sustained changes in patella position post taping and exercise. <sup>63</sup> This reduction in VMO activity with tape during the step test, may also be explained by the position of the tape. The tape is applied very closely to the VMO electrode and causes some gathering of the skin, which may have moved the surface electrode. However, this is unlikely as other studies <sup>60,73</sup> have used the same method of taping and surface electrode placement as performed in this study, and found an increase in VMO EMG activity <sup>73</sup> or no change in VMO EMG activity with tape. <sup>60</sup> Herrington and Payton <sup>48</sup> used three surface EMG electrodes per muscle and Cerny <sup>11</sup> used wire electrodes, therefore this skin gathering, would possibly not have affected their results in the same way. In addition, the medial patellar tape may result in a decreased knee flexion during the functional tests as subjects subjectively report greater difficulty in flexing the knee fully post tape application. This possible decrease in knee flexion during activity may decrease the overall VMO EMG activity. Previous studies <sup>5,9,101</sup> have shown that VMO is least active in the extended position and most active between 60° and 90° knee flexion as torque increases. Therefore, decreased knee flexion whilst stepping with tape, that is, a type of “quadriceps avoidance” or

straight leg gait, may result in the decrease in VMO EMG activity. However, this theory is in contrast to the literature as Powers et al<sup>84</sup> found an increase in stride length and an increase in knee flexion in response to loading (stance phase of walking) in PFP subjects with tape. Further kinematic research would need to be undertaken to determine further effects of tape on gait patterns.

VL activity was not altered significantly by tape during any of the tests suggesting that this taping technique had more effect on the VMO rather than the VL muscles.

A larger percentage of type 1 fibres are found in the vastus medialis (61.5 %) compared to the VL (46.9 %).<sup>55</sup> Type 1 (slow twitch) fibres tend to dominate in primary postural muscles (tonic) providing active stability to a joint, whereas type 2 (fast twitch) fibres tend to dominate in muscles (phasic) producing greater speed of movement and force.<sup>106</sup> It is not known if tape produces a different effect on tonic as opposed to phasic muscles.

#### 3.5.3.2 Force/EMG

Force/EMG is used to determine the amount of force produced by a certain percentage of recruited muscle fibres. The greater the force with recruitment of less muscle fibres, the greater the muscle efficiency.<sup>22</sup> Results could only be obtained from the open chain tests as force was not measured during the closed chain tests. The PFP group had smaller ratios than the control group in every test. Peak force/EMG ratios for the VMO were significantly less during all the concentric and eccentric tests in the PFP compared to the control group. In addition, peak force/EMG values for VMO during the MIVC test, were

significantly greater with tape compared to the placebo in both PFP and control groups. This indicates a greater efficiency in force production with tape compared to placebo (but not compared to the no tape condition) during this isometric strength test in both the PFP and control group. In this test (MIVC), tape appears to exert a different effect on the patella compared to the placebo. Force/EMG ratios for the VL were significantly less in the PFP group during all the MIVC and eccentric tests, but not during the concentric tests. There appears to be a general trend, irrespective of the taping condition, for the PFP group to be consistently less efficient in force production per amount of muscle recruitment than the control group. However, this statement is made cautiously due to the confounding effect of the PFP subjects possibly being unable to perform a maximal contraction during this maximal test.

#### 3.5.3.3 VMO/VL

It is useful to compare the activity of VMO relative to VL in order to detect any imbalance in quadriceps activity. The literature suggests that there is no significant difference in VMO/VL ratio between PFP and control subjects.<sup>7,10,11,62,82,86,96,98,101,104</sup> However, several studies show a significant decrease in VMO/VL ratio in PFP versus control subjects during open chain tests,<sup>101</sup> using non normalised EMG data,<sup>98</sup> in PFP subjects with patella subluxation,<sup>70</sup> or in PFP subjects with significantly increased Q angle.<sup>7</sup>

In accordance with most of the literature, this study showed no differences in VMO/VL ratios between PFP and control subjects, except during the placebo MIVC test where PFP

subjects had a significantly greater ratio than control subjects. In addition, PFP and control groups responded differently to treatment of placebo and tape during this MIVC test (significant treatment  $\times$  group interaction). Once again, tape in this test (MIVC) appears to exert a different effect compared to the placebo tape. During the closed chain (step) tests, both control and PFP groups with tape produced smaller VMO/VL ratios. This was most likely due to the large reduction in VMO activity with tape during closed chain testing as previously discussed.

In the literature, a wide range of values for VMO/VL exist, and are considered normal. These values vary according to the range of movement as well as the type of activity (closed or open chain exercise). VMO/VL values in control subjects during knee extension range from 0.9 to 2 (open chain) and 0.7 to 1.62 (closed chain). Similarly, VMO/VL values in PFP subjects during knee extension range from 0.8 to 2.3 (open chain) and 0.8 to 1.5 (closed chain).<sup>7,10,11,49,62,86,89,96,98,101,104</sup>

VMO/VL ratios, in this study, were similar in the control and PFP groups ranging from 0.9 to 1.1 (open chain) and 1.1 to 1.5 (closed chain) in the control group, whereas the PFP group ranged from 0.9 to 1.1 (open chain) and 1.2 to 1.5 (closed chain). In this study, the VMO/VL ratio with no tape and placebo is significantly greater during the closed chain tests compared to the open chain tests in both the PFP and control group. This is in contrast to the trends previously mentioned in the literature where VMO/VL ratio during the open chain tests appeared greater than the closed chain tests. The fact that the closed chain test in this study was submaximal and the open chain test was maximal, may make

comparison of these data unreliable. However, this enhanced VMO/VL ratio during the step test may suggest that closed chain exercises are the recommended form of exercise if enhanced VMO activity in rehabilitation is required. Further research is necessary to substantiate this claim and to determine if rehabilitation is enhanced with exercise at a greater VMO/VL ratio. It is important to note that in this study, this VMO/VL ratio is only significantly greater in the closed chain test as opposed to the open chain test when the patella is not medially taped. This is probably a reflection of the reduction in recorded VMO EMG activity during the step tests with tape, which has previously been discussed.

#### 3.5.3.4 *Time of Onset of VMO and VL*

In asymptomatic subjects, coactivation of VMO and VL has been most commonly reported.<sup>15,16,58,78,82,96,107,113</sup> Coactivation implies no significant difference in time of onset of VMO relative to VL. In this study, the control group showed no significant differences in onset of activation of VMO relative to VL between taping conditions during any of the tests.

Visual determination of onset of VMO and VL has shown to be reliable in this study, which is in accordance with the literature,<sup>50</sup> except during the eccentric test with no tape and during the MIVC test with the placebo. As a result of poor reliability of the data in both these tests (eccentric test with no tape and the MIVC with placebo), the data were excluded from the discussion.

Many studies have shown no difference between PFP subjects and control subjects regarding onset of activation of VMO and VL<sup>58,78,82</sup> and the onset of peak activation of VMO and VL.<sup>96</sup> However, some studies<sup>15,16</sup> have reported a delay in the onset of activation of VMO in PFP subjects during functional tests. After reflex testing by patellar tendon tap, Voight and Weider<sup>107</sup> found earlier onset of activation of VL in PFP subjects whereas the onset of activation of VMO was no different between PFP and control subjects. In a similar study by Witvrouw et al,<sup>113</sup> PFP subjects showed earlier onset of activation of VL whereas the control subjects activated VMO first. Both these reflex studies must be interpreted with caution as Karst and Willett<sup>58</sup> found a lack of association between the onset of activation for reflex activity and active knee extension of VMO and VL. This suggests that reflex testing is not a good indicator of relative timing of voluntary muscle activity.

A delay in the onset of activation of VMO relative to VL occurred during the MIVC test, with no tape and tape in the PFP compared to the control group, in this study. However, no significant difference in the time of onset of activation of VMO relative to VL, between PFP and control subjects, occurred during all the other tests (concentric, eccentric and step), which confirms the result of previous studies.<sup>58,78,82,96</sup> Studies with contrasting findings,<sup>15,16</sup> are different to this study in task specificity, data analysis and statistical tests used, which may have produced differing results. For instance, in this study subjects took 3 seconds per step, whereas, Cowan et al<sup>15</sup> had subjects stepping at a 0.6 seconds per step. In the study by Cowan et al,<sup>16</sup> onsets of EMG activity were expressed relative to the prime mover, in this case, tibialis anterior. However, both this

study and Cowan et al,<sup>16</sup> found a large individual subject variation for onsets of VMO and VL in both PFP and control groups.

Interestingly, in this study, tape produced no change in the onset of activation of VMO relative to VL in PFP subjects and control subjects during any of the tests. This is in contrast to the findings of Gilleard et al<sup>40</sup> who reported that taping resulted in an earlier activation of VMO during a step test. The results of the latter study must be interpreted with caution due to statistical and methodological concerns regarding the variety of taping techniques used,<sup>73</sup> small sample size, lack of randomisation, placebo, and asymptomatic control subjects, as well as the exclusion of the subjects whose pain interfered with testing. Taping has been shown to significantly delay onset of activation of the VMO and the VL during stair ascent (with no change on stair descent), in asymptomatic subjects.<sup>79</sup> This delay in onset of VMO and VL with tape is possibly due to the tape's cutaneous stimulation affecting threshold of recruitment of motor units, or an attempt by the motor control system to counter the mechanical effect of the change in patella movement.

#### 3.5.4 Summary

##### 3.5.4.1 *The Differences Between the PFP and Control Subjects (no tape)*

PFP subjects experienced more pain with testing, produced less force (with the exception of the peak eccentric test), and produced greater VMO EMG activity during the step tests than control subjects. VL EMG activity and VMO/VL showed no differences between groups. Muscle efficiency (force/EMG) was less in the PFP compared to the control

group for VMO and VL during most of the tests. There were no differences in onset of activation of VMO relative to VL during all the isokinetic and step tests. However, delayed onset of activation of VMO relative to VL occurred in the PFP compared to the control group during the isometric strength test.

#### 3.5.4.2 *The Effect of the Placebo*

The placebo condition was not significantly different to the no tape condition during any test in the PFP and control group.

During the MIVC test, the muscle efficiency (force/EMG for VMO) of the PFP and control group was less with placebo compared to tape, but no different to the no tape condition. In addition, during the MIVC test, the VMO/VL ratio responded differently to treatment of placebo and tape comparing the PFP and control group (significant treatment  $\times$  group interaction). The placebo produced a significantly greater VMO/VL ratio in the PFP compared to the control group, during the MIVC test.

Therefore, some differences were noted between the placebo and tape conditions in the MIVC test, but not in the concentric, eccentric and step tests. The PFP subject's perceptions of their disorder and expectations of treatment may have been a contributory factor.

#### 3.5.4.3 *The Effect of Tape*

In the PFP group, tape did not result in a decrease in pain. In addition, in both the PFP and control group, tape did not change force output nor produce a change in VMO or VL EMG activity during open chain tests. However, during the closed chain (step) tests, tape produced a significant decrease in VMO activity during the step up and step down tests in both groups. In addition, VMO/VL was decreased during the step tests possibly on account of the marked decrease in the VMO activity. No change was noted in force/EMG for VMO nor VL, in both groups. No change was noted with taping for the onset of activation of VMO relative to VL in both groups.

Cutaneous mechanoreceptors in the skin are directionally sensitive to skin stretch,<sup>31,36</sup> and altered recruitment threshold and order of motor unit recruitment may occur with cutaneous stimulation.<sup>36,54</sup> Therefore, any application of tape, whether it be a placebo or tape producing a medial glide on the skin, may have an effect on recruitment of muscle fibres and affect muscle function. As the medial patellar tape produced a strong medially directed skin strain pattern, an enhanced cutaneous stimulation may have occurred, possibly affecting the brain's assessment of joint position.<sup>31</sup>

#### 3.5.5 Limitations of this study

This study was designed to address limitations of previous studies and as such was a randomised, placebo and patient controlled clinical trial. However, this study was limited by the relatively small sample size, the low repetitions of testing, and the fact that it was the first time the subjects were exposed to the tape. In addition, PFP covers a wide variety

of injuries therefore different groups of PFP subjects may be affected differently by taping. This study was limited to PFP subjects participating in sport. Many authors have stressed the importance of the classification of PFPS.<sup>34,51,110</sup> In this study, strict exclusion and inclusion criteria were adhered to. However, the causes of the PFP were not further investigated which would have allowed the subjects to be classified according to the structure at fault as was done in a study by Vaatainen et al.<sup>104</sup>

Limitations in the method of testing exist. Tape with a medial glide component was used alone, therefore these findings are specific to this taping technique, irrespective of the appropriateness of its use in each subject. Regarding pain scores, differentiating between the concentric and eccentric isokinetic tests would have highlighted any possible discrepancies. The MIVC tests were performed at 60° of knee flexion only, limiting generalisation of this data. The step test was performed at a slow speed of 3 seconds per step, which is not usual walking pace. Normalisation of EMG data may have introduced error during the step test when comparing the control with the PFP subjects due to the PFP subjects being unable to perform the maximal open chain test maximally as a result of pain. Regarding data analysis no computer algorithm was used to determine the time of onset of activation of VMO and VL. Visual analysis was performed alone, however this has shown to be acceptable.<sup>50</sup>

### 3.5.6 Future Research

Future research may improve on the limitations expressed, regarding this study. In addition, regarding testing procedures, pain scores taken before and after each test would

enhance accuracy of the contribution of the test to resting pain. Maximal open chain and submaximal closed chain tests were performed and compared in this study. Future studies could compare maximal open chain and maximal closed chain or submaximal open chain and submaximal closed chain tests. The step test could be improved in future studies by separating the step up from the step down so that two sets of data for determination of the onset of activation of VMO and VL could be analysed. Research involving the use of different taping techniques or the effects of tape on different muscle types (tonic compared to phasic muscles) may add to our clinical knowledge on the effects of tape. As a wide variety of disorders may be classified as PFP, the large individual variation of PFP subjects may result in a varied response to taping. Further research on the effects of tape on PFP subjects separated into different groups according to a classification system, may yield differing results.

The aim of further research is to increase our knowledge of the patellofemoral joint mechanics, especially in individuals with PFPS and to analyse interventions effective in the treatment of PFP by means of clinical trials. Of great value would be to establish the role of the VMO (as well as other quadriceps muscles) in contributing to the biomechanics of the patellofemoral joint and PFP. In addition, future research should aim at identifying mechanisms by which treatment procedures affect the biomechanics, for example various strapping techniques or muscle strengthening programmes.

### 3.6 CONCLUSION

In this study, differences between the PFP and control subjects with respect to pain, force output and neuromuscular recruitment exist. The PFP group, compared to the control group, experienced significantly more pain with testing, produced 21 % less quadriceps force during all tests, produced less force/EMG (muscle efficiency) during most tests, produced 29 % greater VMO EMG activity during the step tests, and produced no difference in time of onset of VMO relative to VL during the isokinetic and step tests, with delayed onset of activation of VMO relative to VL during the isometric strength test. There were no significant differences in VL EMG activity or VMO/VL ratio between the PFP and the control groups with no tape.

The clinical implications of this study are that medial patellar tape, as used in this study, did not result in: a significant reduction in pain, a significant increase in quadriceps force output or a significant change in the time of onset of activation of VMO relative to VL, in the PFP group. However, tape did produce a 17 % decrease in VMO EMG activity and a decrease in VMO/VL ratio during the step tests in both the PFP and control groups. As tape did produce consistent and significant changes in neuromuscular recruitment in control and PFP subjects, tape does seem to have an effect on the neuromechanics of the patella, but possibly not the proposed effects initially suggested. It is not clear if these effects would have any clinical benefit in individuals with PFP.

### 3.7 TABLES

**TABLE 1**

**Anthropometrical data for the control (n=20) and PFP (n=15) group.**  
(Data are expressed as the mean  $\pm$  SD).

<b>Variables</b>	<b>Control</b>	<b>PFP</b>
Mass (kg)	64.4 $\pm$ 11.1	65.2 $\pm$ 9.6
Age (yrs)	29.4 $\pm$ 4.6	29.1 $\pm$ 5.1
Lean Thigh Volume (cm <sup>3</sup> )	3267 $\pm$ 535	3324 $\pm$ 712
Body Mass Index (kg/m <sup>2</sup> )	22.4 $\pm$ 2.2	22.8 $\pm$ 1.8
Sum of Skinfolds (mm)	87.7 $\pm$ 24.1	98.9 $\pm$ 37.2
% muscle	49.1 $\pm$ 3.3	47.7 $\pm$ 4.9
% fat	22.0 $\pm$ 4.4	23.7 $\pm$ 6.8
Lean Body Mass (kg)	50.3 $\pm$ 9.5	49.9 $\pm$ 9.7

**TABLE 2**

**Results of control and PFP subjects during maximum isometric voluntary contraction (MIVC), concentric/eccentric and step tests with no tape, placebo and tape conditions with regard to pain.**  
(Data are expressed as the mean  $\pm$  SD).

	CONTROL			PFP *		
	No Tape	Placebo	Tape	No Tape	Placebo	Tape
<b>Pain (VAS)</b>						
-MIVC	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	0.0 $\pm$ 0.1	1.8 $\pm$ 1.6	2.2 $\pm$ 1.8	1.8 $\pm$ 1.5
-conc/ecc	0.0 $\pm$ 0.0	0.1 $\pm$ 0.4	0.0 $\pm$ 0.0	2.2 $\pm$ 1.7	2.5 $\pm$ 1.9	2.0 $\pm$ 1.6
-step	0.1 $\pm$ 0.3	0.0 $\pm$ 0.0	0.0 $\pm$ 0.0	1.0 $\pm$ 1.2	1.0 $\pm$ 1.1	1.1 $\pm$ 1.5

\* PFP vs control ( $p < 0.05$ )

No treatment differences, no interaction between treatment  $\times$  group

**TABLE 3**

**Results of control and PFP subjects during maximum isometric voluntary contraction (MIVC), concentric, eccentric and step tests with no tape, placebo and tape conditions with regard to quadriceps force output and EMG activity.**

(Data are expressed as the mean  $\pm$  SD).

	CONTROL			PFP		
	No Tape	Placebo	Tape	No Tape	Placebo	Tape
<b>Peak Force</b>						
-MIVC (N)	518 $\pm$ 96	516 $\pm$ 111	510 $\pm$ 97	430 $\pm$ 117*	409 $\pm$ 90*	436 $\pm$ 126*
-conc (Nm)	124 $\pm$ 28	119 $\pm$ 27	125 $\pm$ 27	94 $\pm$ 31*	86 $\pm$ 29*	92 $\pm$ 37*
-ecc (Nm)	180 $\pm$ 54	182 $\pm$ 51	179 $\pm$ 49	155 $\pm$ 57	146 $\pm$ 51	154 $\pm$ 42
<b>Mean Force</b>						
-MIVC (N)	458 $\pm$ 83	451 $\pm$ 109	453 $\pm$ 87	362 $\pm$ 94*	348 $\pm$ 75*	376 $\pm$ 108*
-conc (J)	112 $\pm$ 26	109 $\pm$ 25	113 $\pm$ 25	84 $\pm$ 23*	77 $\pm$ 23*	82 $\pm$ 30*
-ecc (J)	156 $\pm$ 41	156 $\pm$ 42	154 $\pm$ 43	132 $\pm$ 46*	119 $\pm$ 40*	131 $\pm$ 32*
<b>EMG VMO (%)</b>						
-MIVC	100 $\pm$ 0	103 $\pm$ 21	105 $\pm$ 48	100 $\pm$ 0	107 $\pm$ 36	93 $\pm$ 27
-conc	138 $\pm$ 33	134 $\pm$ 43	135 $\pm$ 51	138 $\pm$ 49	129 $\pm$ 31	141 $\pm$ 71
-ecc	108 $\pm$ 26	113 $\pm$ 40	111 $\pm$ 62	122 $\pm$ 37	118 $\pm$ 40	136 $\pm$ 87
-step up	60 $\pm$ 23	62 $\pm$ 21	47 $\pm$ 15 <sup>‡</sup>	77 $\pm$ 27*	77 $\pm$ 28*	64 $\pm$ 20 <sup>‡</sup>
-step down	66 $\pm$ 23	65 $\pm$ 20	55 $\pm$ 21 <sup>‡</sup>	85 $\pm$ 28*	81 $\pm$ 22*	72 $\pm$ 23 <sup>‡</sup>
<b>EMG VL (%)</b>						
-MIVC	100 $\pm$ 0	110 $\pm$ 24	106 $\pm$ 27	100 $\pm$ 0	97 $\pm$ 27	110 $\pm$ 94
-conc	136 $\pm$ 34	131 $\pm$ 41	136 $\pm$ 36	153 $\pm$ 75	127 $\pm$ 52	147 $\pm$ 94
-ecc	123 $\pm$ 37	122 $\pm$ 42	118 $\pm$ 34	141 $\pm$ 70	127 $\pm$ 41	143 $\pm$ 58
-step up	49 $\pm$ 17	46 $\pm$ 19	45 $\pm$ 16	61 $\pm$ 37	62 $\pm$ 37	60 $\pm$ 36
-step down	55 $\pm$ 25	56 $\pm$ 20	54 $\pm$ 19	70 $\pm$ 37	69 $\pm$ 39	66 $\pm$ 34
<b>VMO/VL</b>						
-MIVC $\blacklozenge$	1.0 $\pm$ 0.0	1.0 $\pm$ 0.2	1.0 $\pm$ 0.3	1.0 $\pm$ 0.0	1.1 $\pm$ 0.2 <sup>Δ</sup>	0.9 $\pm$ 0.3
-conc	1.0 $\pm$ 0.2	1.1 $\pm$ 0.2	1.0 $\pm$ 0.3	1.0 $\pm$ 0.2	1.1 $\pm$ 0.2	1.1 $\pm$ 0.5
-ecc	0.9 $\pm$ 0.2	1.0 $\pm$ 0.2	0.9 $\pm$ 0.4	0.9 $\pm$ 0.3	1.0 $\pm$ 0.3	1.0 $\pm$ 0.6
-step up	1.4 $\pm$ 0.5	1.5 $\pm$ 0.6	1.1 $\pm$ 0.4 <sup>‡</sup>	1.5 $\pm$ 0.8	1.5 $\pm$ 0.7	1.3 $\pm$ 0.6 <sup>‡</sup>
-step down	1.3 $\pm$ 0.4	1.2 $\pm$ 0.4	1.1 $\pm$ 0.3 <sup>‡</sup>	1.4 $\pm$ 0.5	1.4 $\pm$ 0.5	1.2 $\pm$ 0.5 <sup>‡</sup>
<b>Force/EMG VMO</b>						
-MIVC	518 $\pm$ 96	514 $\pm$ 133	551 $\pm$ 189*	430 $\pm$ 117	414 $\pm$ 136	500 $\pm$ 187*
-conc	97 $\pm$ 32	99 $\pm$ 41	109 $\pm$ 41	76 $\pm$ 39*	70 $\pm$ 28*	74 $\pm$ 37*
-ecc	174 $\pm$ 54	177 $\pm$ 67	202 $\pm$ 85	133 $\pm$ 50*	137 $\pm$ 66*	148 $\pm$ 94*
<b>Force/EMG VL</b>						
-MIVC	518 $\pm$ 96	484 $\pm$ 125	503 $\pm$ 139	430 $\pm$ 117*	444 $\pm$ 136*	403 $\pm$ 95*
-conc	98 $\pm$ 37	100 $\pm$ 37	101 $\pm$ 36	72 $\pm$ 41	77 $\pm$ 43	73 $\pm$ 40
-ecc	159 $\pm$ 71	166 $\pm$ 75	164 $\pm$ 65	119 $\pm$ 40*	121 $\pm$ 43*	117 $\pm$ 37*

\* PFP vs control ( $p < 0.05$ )

<sup>‡</sup> Tape vs no tape and placebo ( $p < 0.05$ )

\* Tape vs placebo ( $p < 0.05$ )

$\blacklozenge$  Treatment  $\times$  group interaction ( $p < 0.05$ )

<sup>Δ</sup> PFP placebo vs control placebo ( $p < 0.05$ )

**TABLE 4**

**Results of a pilot study (on 5 subjects, on 3 occasions) to ascertain tester reliability in visual determination of onset of activation of VMO and VL (ms).**

(Data are expressed as the mean  $\pm$  SD).

<b>DATA</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>No tape</b>			
-MIVC	-72 $\pm$ 56	-68 $\pm$ 52	-58 $\pm$ 55
-conc	-32 $\pm$ 39	-25 $\pm$ 34	-22 $\pm$ 29
-ecc	-21 $\pm$ 22*	-6 $\pm$ 27	-11 $\pm$ 26
-step	-26 $\pm$ 72	-28 $\pm$ 86	-21 $\pm$ 91
<b>Placebo</b>			
-MIVC	-61 $\pm$ 69*	-44 $\pm$ 77	-52 $\pm$ 73
-conc	14 $\pm$ 108	17 $\pm$ 105	8 $\pm$ 110
-ecc	-23 $\pm$ 34	-21 $\pm$ 34	-32 $\pm$ 48
-step	-33 $\pm$ 45	-32 $\pm$ 77	-45 $\pm$ 68
<b>Tape</b>			
-MIVC	-94 $\pm$ 75	-89 $\pm$ 68	-86 $\pm$ 81
-conc	-64 $\pm$ 47	-42 $\pm$ 54	-57 $\pm$ 53
-ecc	-15 $\pm$ 27	-14 $\pm$ 39	-29 $\pm$ 40
-step	-64 $\pm$ 83	-54 $\pm$ 78	-55 $\pm$ 84

\* Data 1 vs Data 2 and 3 ( $p < 0.05$ )

\* Data 1 vs Data 2 ( $p < 0.05$ )

**TABLE 5**

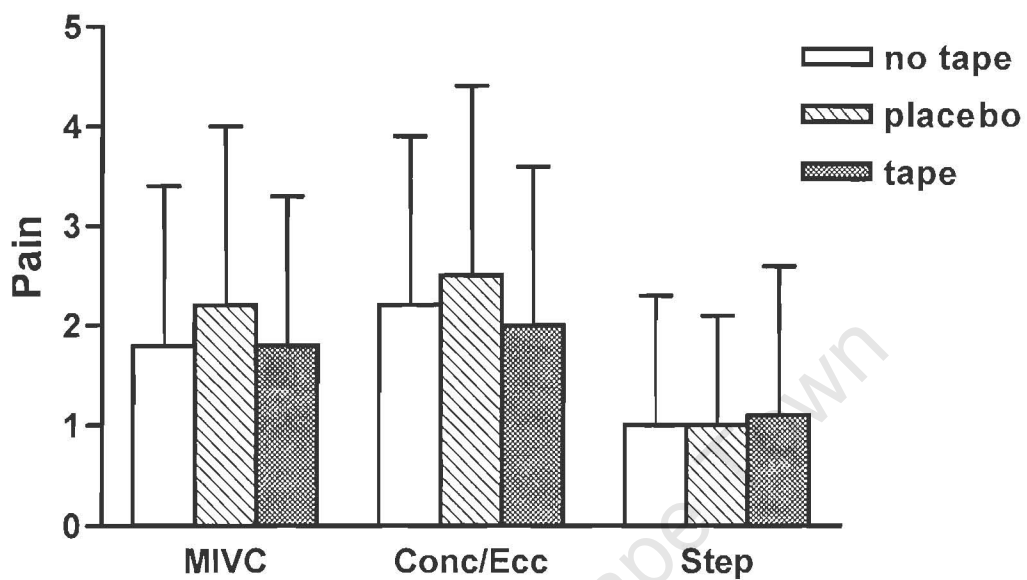
Results of control and PFP subjects during maximum isometric voluntary contraction (MIVC), concentric, eccentric and step up tests with no tape, placebo and tape conditions with regard to the time (ms) elapsed between onset of activation of VMO and VL (a positive result indicates an earlier onset of activation of VL).

(Data are expressed as the mean  $\pm$  SD).

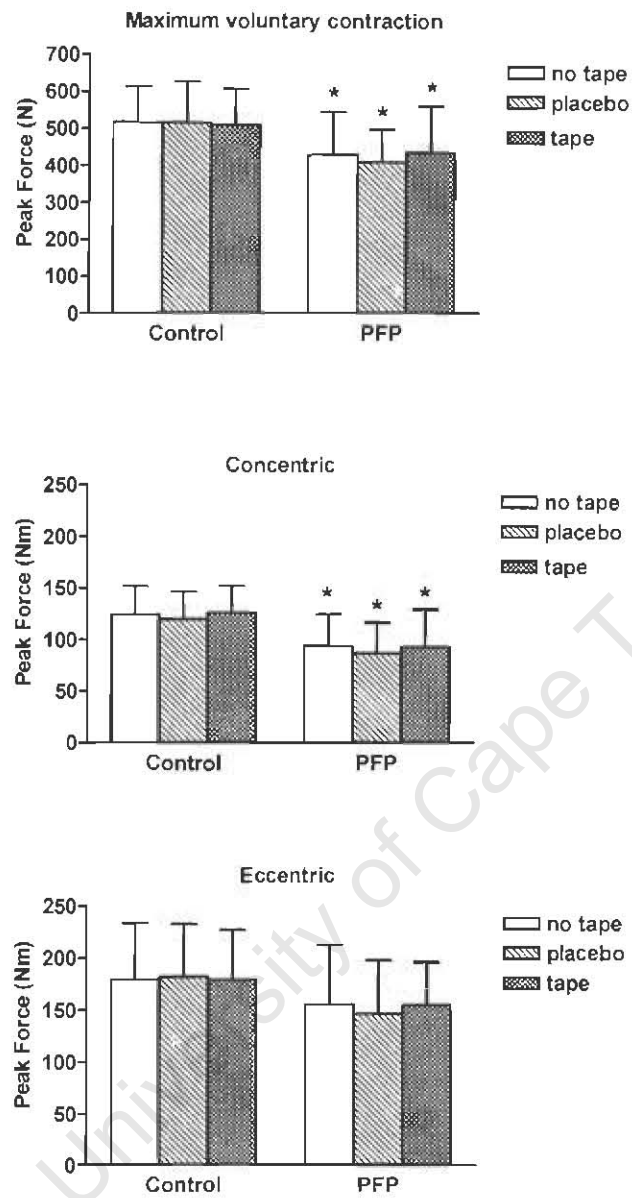
	CONTROL			PFP		
	No tape	Placebo	Tape	No Tape	Placebo	Tape
<b>Timing</b>						
VMO-VL(ms)						
-MIVC	8 $\pm$ 35	18 $\pm$ 82	1 $\pm$ 25	31 $\pm$ 47*	42 $\pm$ 56*	47 $\pm$ 59*
-conc	3 $\pm$ 21	5 $\pm$ 17	5 $\pm$ 27	10 $\pm$ 31	5 $\pm$ 65	36 $\pm$ 42
-ecc	26 $\pm$ 55	12 $\pm$ 28	17 $\pm$ 29	-15 $\pm$ 134	32 $\pm$ 36	21 $\pm$ 30
-step up	-3 $\pm$ 52	15 $\pm$ 99	33 $\pm$ 68	12 $\pm$ 60	37 $\pm$ 71	-13 $\pm$ 134

\* PFP vs control ( $p < 0.05$ )

## 3.8 FIGURES

**FIGURE 1**

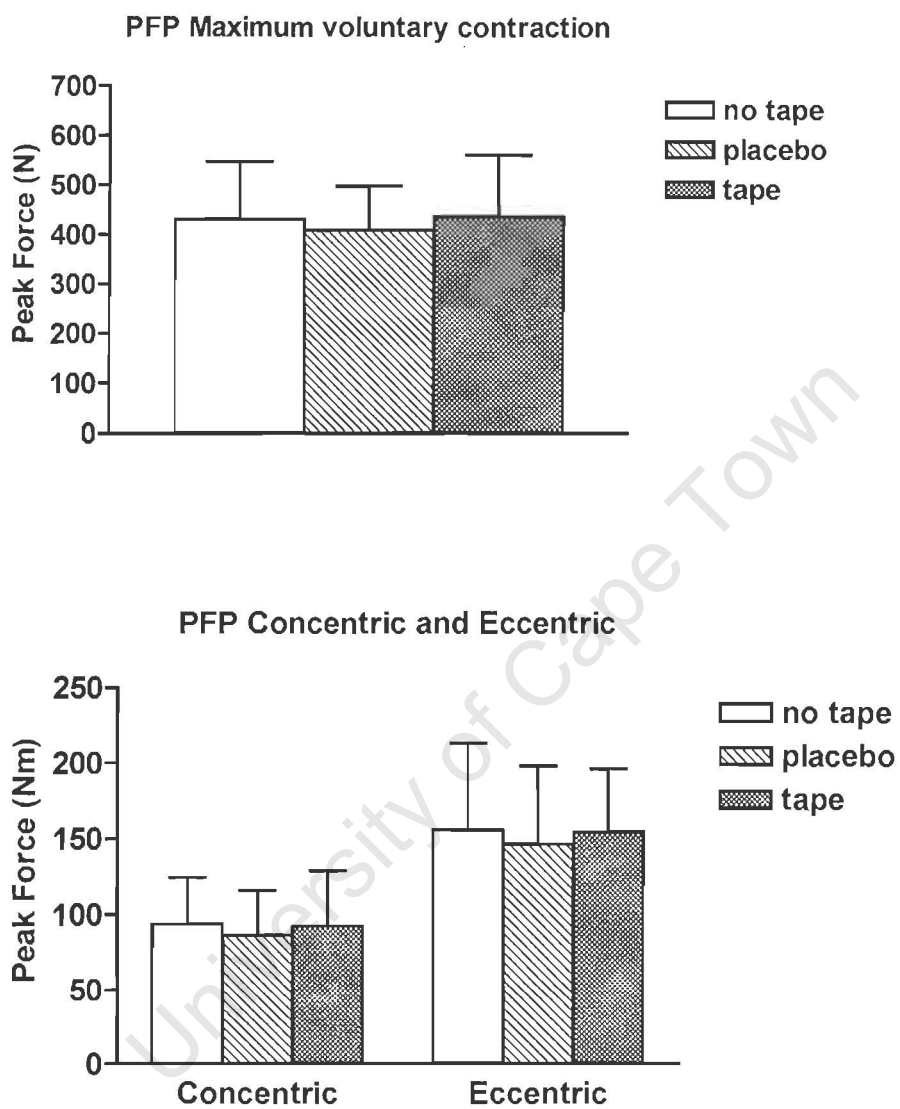
Pain (as measured on the visual analogue scale, 1-10) in the PFP group during the MIVC, concentric/eccentric and step tests with no tape, placebo and tape.



**FIGURE 2**

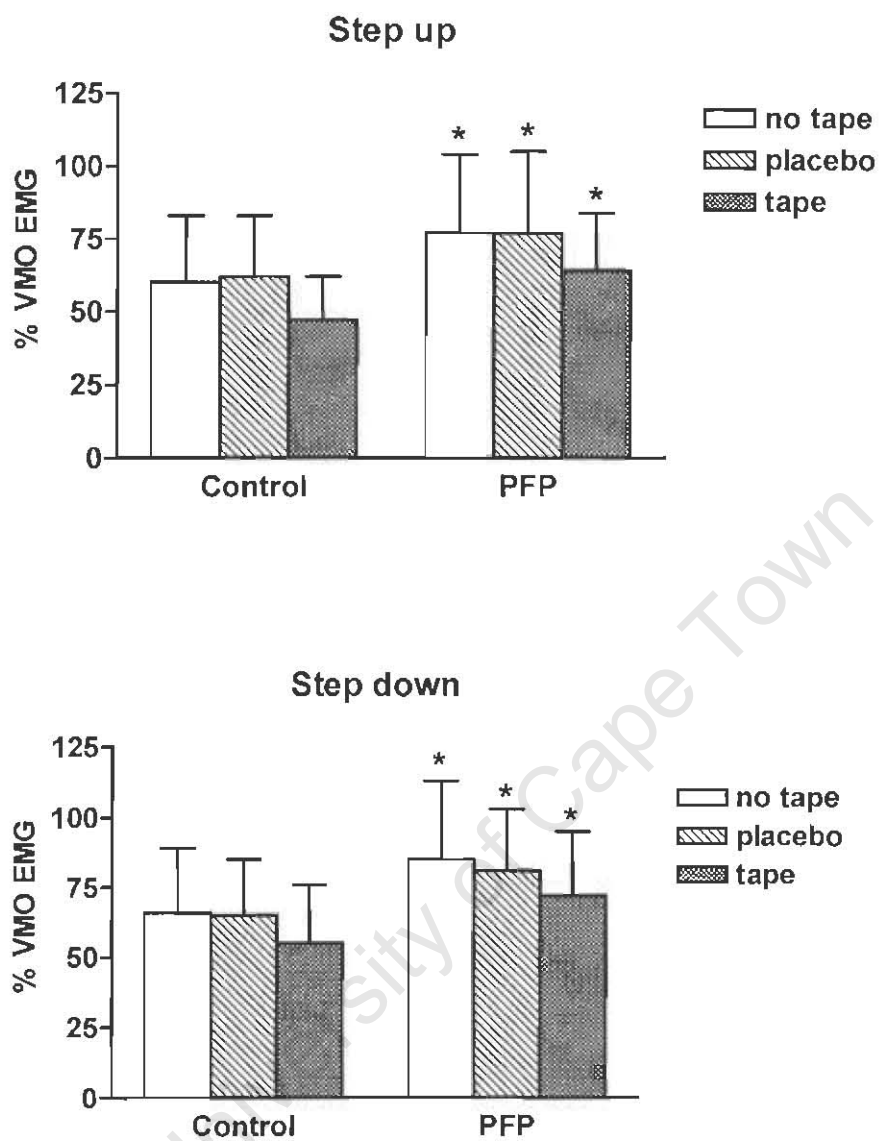
Peak quadriceps force output comparing the control and PFP groups during the MIVC (N), concentric and eccentric tests (Nm) with no tape, placebo and tape.

(\* PFP vs control;  $p < 0.05$ )



**FIGURE 3**

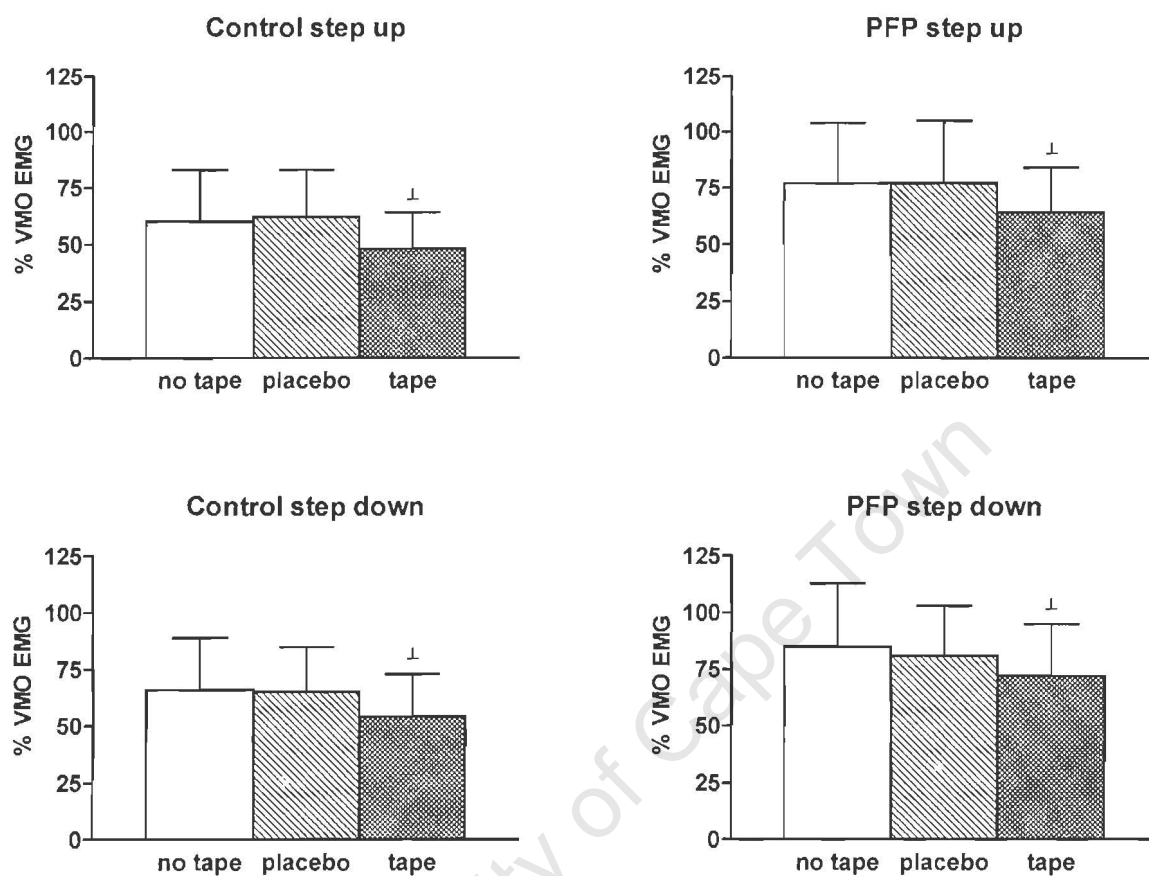
Peak quadriceps force output in the PFP group during the MIVC (N), concentric and eccentric (Nm) tests with no tape, placebo and tape.



**FIGURE 4**

**% VMO EMG activity comparing the control and PFP groups during step up and step down tests with no tape, placebo and tape.**

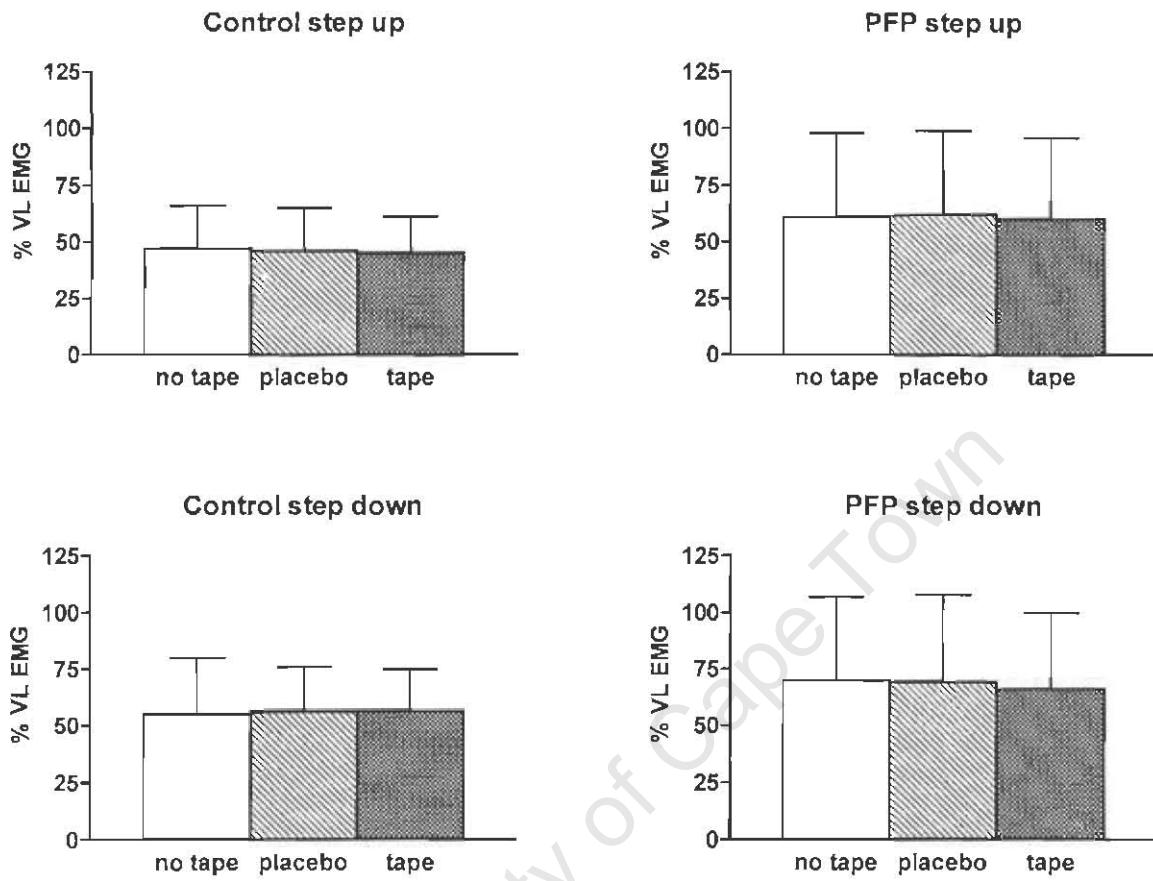
(\* PFP vs control;  $p < 0.05$ )



**FIGURE 5**

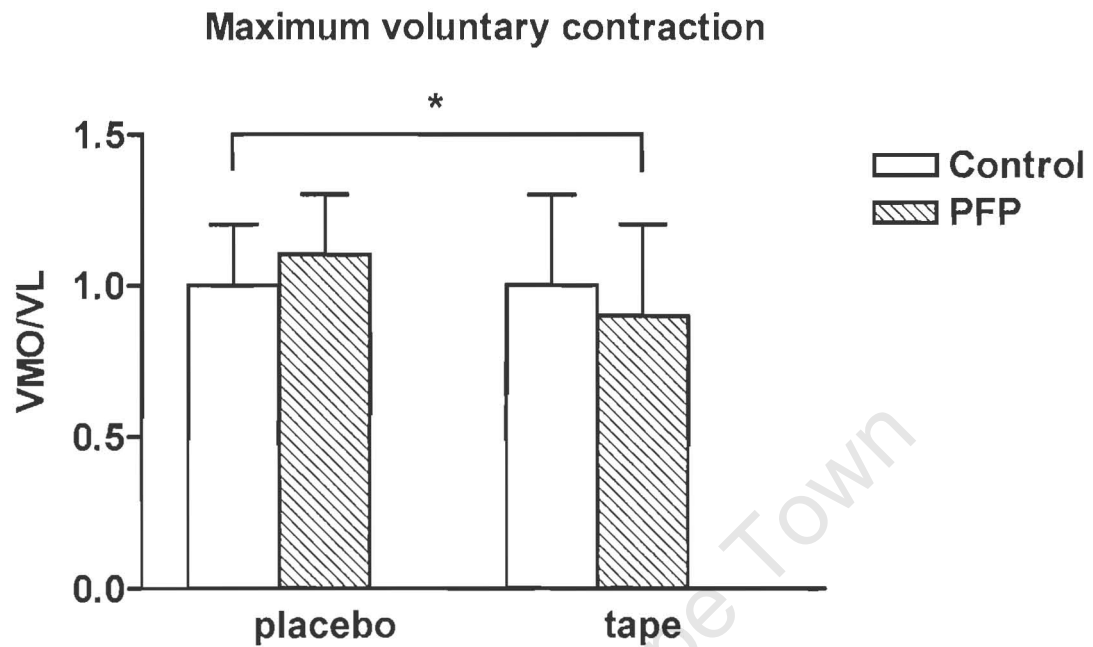
**% VMO EMG activity in the control and PFP groups during the step up and step down tests with no tape, placebo and tape.**

(† Tape vs no tape and placebo;  $p < 0.05$ )



**FIGURE 6**

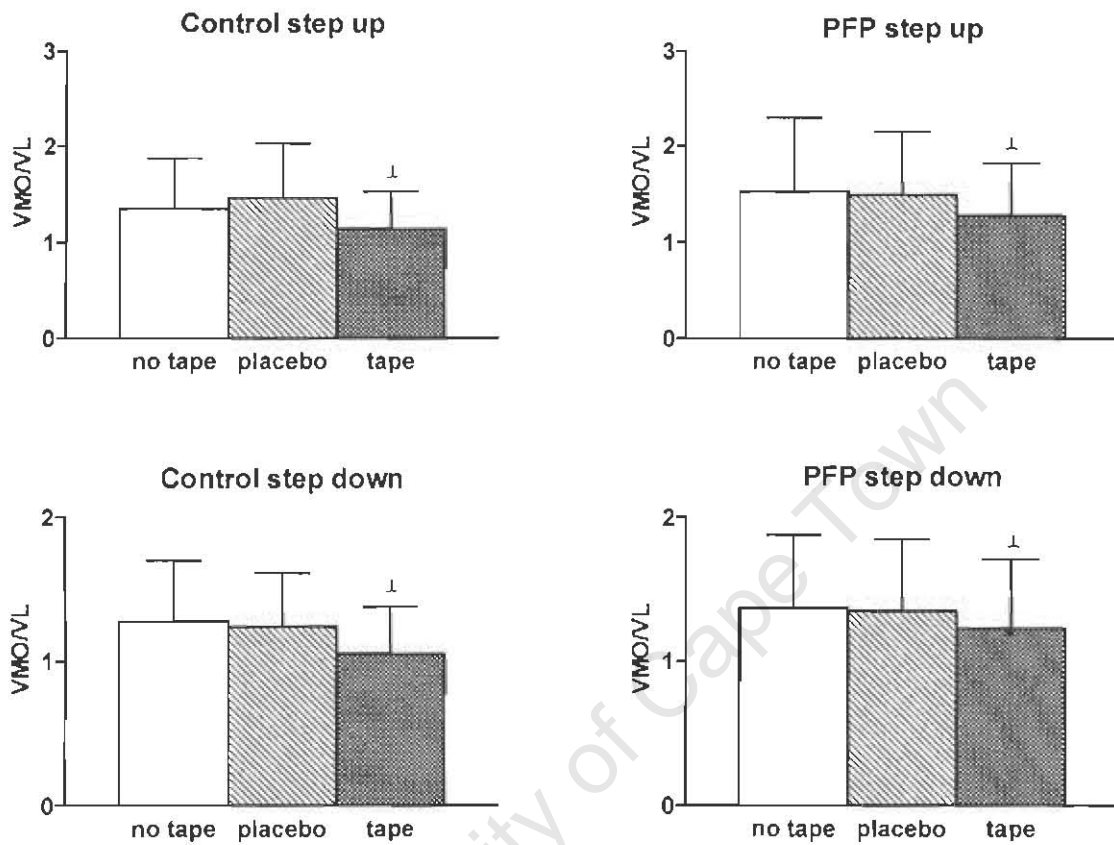
**% VL EMG activity in the control and PFP groups during the step up and step down tests with no tape, placebo and tape.**



**FIGURE 7**

**VMO/VL ratios comparing the control and PFP groups during the MIVC test with placebo and tape.**

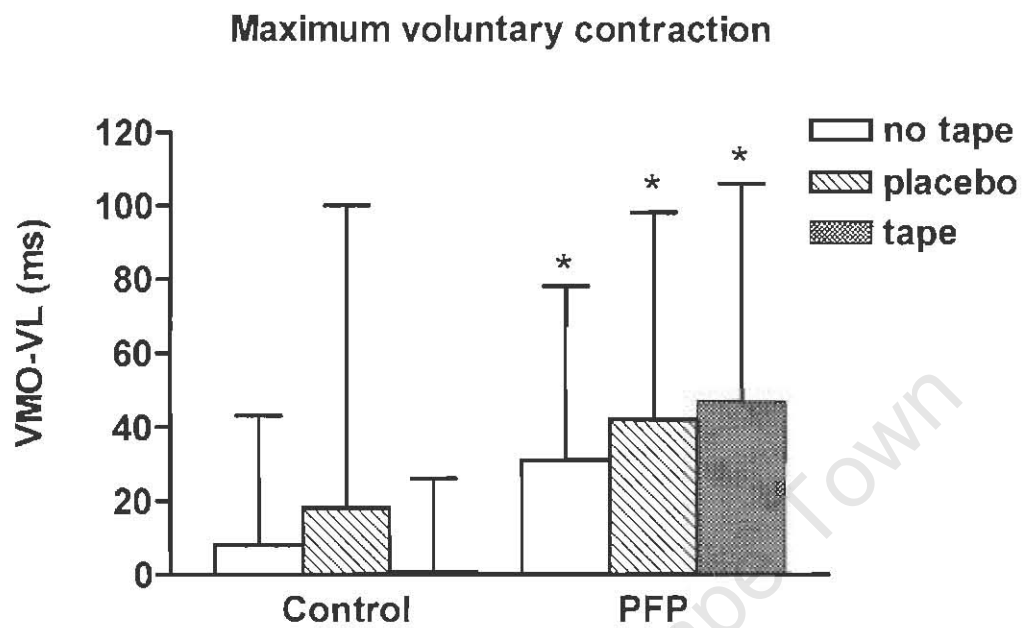
\* interaction (group  $\times$  treatment) ( $p < 0.05$ )  
(Placebo control vs placebo PFP;  $p < 0.05$ )



**FIGURE 8**

VMO/VL ratios in the control and PFP groups during the step up and step down tests with no tape, placebo and tape.

(†Tape vs no tape and placebo;  $p < 0.05$ )



**FIGURE 9**

Differences in the time (ms) of onset of activation of VMO relative to VL, comparing the control and PFP groups during the MIVC test with no tape, placebo and tape.

(\* PFP vs control;  $p < 0.05$ ).

## CHAPTER 4

### CONCLUSION

Patellofemoral disorders are amongst the most common clinical conditions encountered in the sporting and general population resulting in disability regarding activities of daily living and sports participation. It is paramount that a clinician's knowledge and understanding of the patellofemoral joint mechanics, predisposing factors to PFP and treatment modalities currently used, is optimal in order to determine the most effective management of this condition.

Differences between the PFP and the normal population with regard to strength and neuromuscular recruitment, as well as additional factors associated with PFP and the management of this condition with particular reference to the patellar tape has been reviewed. Review of the literature reveals individuals with PFP, firstly, require an evaluation-based classification and thereafter require individual, appropriate, specific interventions. Many of the techniques used by clinicians in the treatment of PFP have not been well defined through research and lack evidence of clinical efficacy. However, PFP patients have shown to improve when they are able to enhance general quadriceps functional patterns through pain-free exercise.

Patellar taping is used by clinicians during the treatment of PFPS, in an attempt to reduce pain, increase strength, enhance neuromuscular recruitment and to correct the timing of onset of activation of VMO relative to VL. Patellar taping in the treatment of PFPS is

most commonly applied directly over the patella with a force aimed at pulling the patella into a medial position (McConnell, 1986). Many hypotheses for the mechanism of action of the patellar tape have been proposed. The literature is unclear as to the effect of tape on pain, strength, EMG activity, patella position, proprioception and gait as well as to the placebo effect of tape.

The research in the study was aimed at determining any differences in strength and neuromuscular recruitment between subjects with PFP and the normal population. The next objective was to study the effect of medial patellar taping on pain, strength and neuromuscular recruitment (quantity and time of onset of EMG activity) during open chain and closed chain exercises in subjects with and without patellofemoral pain.

In this study, differences between the PFP and control subjects with respect to pain, force output and neuromuscular recruitment exist. The PFP group compared to the control group show: 1) increased pain with all tests, 2) decreased quadriceps force output, 3) decreased muscle efficiency (force/EMG) during most tests, 4) increased VMO activity during the step test and 5) no difference in onset of activation of VMO relative to VL during the open and closed chain tests, except during the isometric strength test where delayed onset of VMO relative to VL occurred in the PFP group. There were no significant differences in VL EMG activity or VMO/VL ratio between the PFP and the control groups with no tape.

Medial patellar tape, as used in this study, does not produce a decrease in pain, an increase in quadriceps force output and a change in the onset of activation of VMO relative to VL in the PFP group. However, tape did produce a consistent and significant change in neuromuscular recruitment in control and PFP subjects during the closed chain (step) tests. A decreased VMO EMG activity and decreased VMO/VL ratio was evident during the step tests performed with tape in both the PFP and control groups. Therefore, tape does seem to have an effect on the neuromechanics of the patella, but possibly not the proposed effects initially suggested.

Firstly, it may produce some gait changes resulting in the decreased VMO activity. Decreased knee flexion or a “quadriceps avoidance” gait has been suggested. Secondly, the mechanical effect of the tape, producing skin strain patterns, may effect neuromuscular recruitment due to perceived proprioceptive changes in the joint. Thirdly, as there was a decrease in VMO activity during the step test to perform the same amount of work, this would suggest that the muscle was acting more efficiently. Therefore, taping may be a valuable tool in rehabilitation of PFP subjects. However, rehabilitation studies have shown no additional benefit of adding taping to exercises in the treatment of PFP suggesting that perceived clinical benefits of McConnell strapping may be due to the associated rehabilitation programme.

It is important to note that there a wide variety of disorders may be classified as PFP. The individual variation of PFP subjects may result in a varied response to taping.

Further research on PFP subjects separated into different groups according to a classification system, may yield differing results.

This study highlights the importance of placebo, controlled, clinical trials on treatment interventions in order to investigate popular theories on which management of conditions is based. This increases the clinical knowledge of the mechanisms and efficacy of treatment interventions, which enhances the clinical management of disorders.

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## Appendix 1

### INFORMED CONSENT

**STUDY: THE EFFECT OF MEDIAL PATELLA TAPING ON PAIN, NEUROMUSCULAR RECRUITMENT AND STRENGTH IN SUBJECTS WITH AND WITHOUT PATELLO-FEMORAL PAIN SYNDROME.**

This study is an attempt to determine whether knee taping reduces pain, alters neuromuscular recruitment and strength in subjects suffering from anterior knee pain.

I, the undersigned, have been fully informed about the risks inherent in participation in this trial. I also understand that the following measurements/tests may be conducted on myself during this study:

- Muscle strength tests
- Electromyographic tests
- Body measurement tests
- Step tests

All the above tests have been explained to my satisfaction. I understand that the tests have certain risks, namely that my knee pain may escalate during testing. Should this occur, I am aware that I will have the manual switch to control the testing machine and be able to stop it if necessary. Crushed ice will be available and be applied should any pain arise. If I have had any previous skin irritation from taping or have any concerns about developing skin irritation, I will be excluded from the study. Hypoallergenic tape will be applied to minimize the effects of irritation but should I feel any discomfort, I must let the investigator know immediately. I understand that I will be free to withdraw from the study at any time and that I will not be subjected to any pressure whatsoever to remain in the trial. All the information collected during the study will be treated with the strictest confidentiality and will only be used for scientific purposes. Names and personal particulars will not be released under any circumstances. I will be free to ask any questions about the procedures and results of the study. There will be no financial costs asked of me. I understand that I will receive an estimate of my quadriceps muscle strength and my percentage body fat. In addition, I will be shown how to tape my knee if taping helps to relieve my pain, all of which will occur on completion of the study if I should desire it. I may be referred for physiotherapy should I so require or desire it.

**I, THE UNDERSIGNED, HAVE READ AND UNDERSTOOD THE PURPOSES AND PROCEDURES INVOLVED IN THIS SCIENTIFIC STUDY.**

Date: \_\_\_\_\_  
 Name of subject: \_\_\_\_\_ Signature: \_\_\_\_\_  
 Name of investigator: \_\_\_\_\_ Signature: \_\_\_\_\_  
 Name of witness: \_\_\_\_\_ Signature: \_\_\_\_\_

## Appendix 2

### IMVUME YOKWENZA UVAVANYO

**UFUNDO: IZIQHAMO EZENZIWA LUBOPHO LWESICIKO SEDOLO KWINTLUNGU, KWIMITHAMBO YOLUVO LWEZIHLUNU (RECRUITMENT), KWAKUNYE NAMANDLA APHATHELANE NCZIFO EZIQUKENEYO ZENTLUNGU EZINGAPHA KATHI KWIDOLO.**

Olufundo zinzame ekuqondeni okokuba ubopho lwedolo luyazinciphisa na iintlungu, lukhuthaza imithambo yoluvo lwezihlunu kwakunye namandla aphantelane neentlungu ozivayo ngaphandle edolweni

Mna, mlesi ndiyavuma ukuba ndixelelwe ngazo zonke ingozi ezinokwenzeka koluvavanyo. Ndiyazi futhi ukuba kuza kuvavanywa oku kulandelayo:

- Uvavanyo lwamandla zihlunu
- Uvavanyo kukusebenza kwezihlunu zakho ngombane (Electromyographic test).
- Ukumetelwa kwamalungu omzimba.
- Uvavanyo lwamabakala.

Ndiyazi ukuba oluvavanyo luncengozi ezinje ngokuba iintlungu zedolo zinokuqatsela ngelixa lovavanyo. Ukuba kuthe oku kwenzeka, ndiyazi ukuba ndiyakuba nalo iqhosha lokucima umatshini lo wovavanyo, ndicime, ngokunokwam yakubakho imfuneko. I Dyunivesiti yase Kapa kwakunye nawuphina uMhloli woluphando, akasokuze nangaliphina uhlobo achaphazeleke kingozi eyakuthi ifumaneke ngelixa lovavanyo okanye ngenxa yovavanyo. Ndiyaqonda ukuba ndingaphuma nanini na kolu vavanyo yaye andinyanzelekanga ukuba ndiqhubekeke ndakunga phatheki kakuhle. Iziphumo zoluvavanyo aziyikupapashwa nakubanina koko zakusetyenziswa kwizifundo zobunzululwazi. Amagama kunje nemfihlelo zakho aziyikupapashwa nakubani na. Ndivumelekile ndibuze ngayo yonke inkqubo yoluvavanyo kunye neziphumo zalo.

Ndiyazi ukuba ndakuzuzisa uqikelelo lwamandla ezihlunu (quadriceps) kwakunye nesiqingatha samafutha omzimba. Kwakhona ndiyakuboniswa indlela yokubopha idolu ukubangaba okukubopha kuyazithomalalisa iintlungu, konke oku kuyakwenziwa ekugqityweni kolufundo ukuba ndakuthi dilufune.

Ndiyaqonda ukuba ndikufumana ubuchule malunga nobume bomzimba wam xa ndigqibe uvavanyo ukuba ndiyafuna.

**MNA, NDISAYINILEYO, NDIYIFUNDILE YAYE NDAYIQONDA IMFUNEKO KUNYE NENKQUBO YOLUPHANDO.**

Umhla \_\_\_\_\_

Igama lam \_\_\_\_\_ Uphawu \_\_\_\_\_

Igama lomhleli \_\_\_\_\_ Uphawu \_\_\_\_\_

Igama lonozakuzaku \_\_\_\_\_ Uphawu \_\_\_\_\_

## Appendix 3

### INGELIGTE TOESTEMMING

#### **STUDIE: DIE EFFEK VAN MEDIALE PATELLERE VERBINDING (TAPING) OP PYN, NEUROMUSKULERE WERWING EN KRAG IN PASIENTE MET PATELLOFEMORALE PYN SINDROOM.**

Hierdie studie poog om vas te stel of patellere verbinding pyn verminder en neuromuskulere werwing en spierkrag verbeter in pasiente met anterior knie pyn.

Ek, die ondertekende, is volledig ingelig betreffend die risiko's inherent aan deelname aan hierdie studie. Ek verstaan dat die volgende mates / toetse op my uitgevoer mag word gedurende die studie:

- Spierkrag
- Elektromiografiese toetse
- Liggaamsafmeting toetse
- Trap toetse

Ek besef dat die toetse sekere risiko's behels, naamlik dat my kniepyn mag toeneem gedurende die toetse. As dit sou gebeur, is ek bewus daarvan dat ek die manuele skakelaar het om die toetsmasjien te beheer en kan afskakel indien nodig. Die Universiteit van Kaapstad of enige van die navorsers is geensins verantwoordelik vir enige besering of pyn opgedoen gedurende die studie of as gevolg van die studie nie. Ek begryp dat ek enige tyd mag onttrek van die studie en dat ek geensins onder druk geplaas sal word om die studie te voltooi nie. Al die inligting verkry gedurende die studie is streng konfidensieel en sal slegs vir wetenskaplike doeleindes aangewend word. Ek het die reg om enige vrae te vra omtrent prosedures en uitslae van die studie.

Ek begryp dat ek 'n skatting aangaande my quadriceps spierkrag en liggaamsvet persentasie sal ontvang. Ek sal ook gewys word hoe om my knie te verbind indien dit my sou behaag.

Ek, die ondertekende, het gelees en verstaan die doeleindes en prosedures betrokke in hierdie studie.

Datum: \_\_\_\_\_

Naam van proefpersoon: \_\_\_\_\_ Handtekening: \_\_\_\_\_

Naam van navorser: \_\_\_\_\_ Handtekening: \_\_\_\_\_

Naam van getuie: \_\_\_\_\_ Handtekening: \_\_\_\_\_

## Appendix 4

### MEDICAL AND SPORTING HISTORY QUESTIONNAIRE

Subject name: \_\_\_\_\_ Date: \_\_\_\_\_

Age: \_\_\_\_\_ Male / Female

General Medical History:

Specific Medical History:

Traumatic knee injury \_\_\_\_\_ Yes / No  
 Patella subluxation or dislocation \_\_\_\_\_ Yes / No  
 Ligamentous laxity or injury \_\_\_\_\_ Yes / No  
 Meniscal injury \_\_\_\_\_ Yes / No  
 Low back pain \_\_\_\_\_ Yes / No  
 Hip pain \_\_\_\_\_ Yes / No  
 Other Musculoskeletal injury to either lower extremity \_\_\_\_\_ Yes / No

Retropatella pain: Right / Left

Duration of patellofemoral pain: \_\_\_\_\_

1. Retropatellar/peripatellar pain on physical examination of the patella \_\_\_\_\_ Yes / No
2. Pseudolocking: clicking and a painful or painless "catching" \_\_\_\_\_ Yes / No
3. Pain on walking up or down stairs \_\_\_\_\_ Yes / No
4. Pain or stiffness on prolonged sitting \_\_\_\_\_ Yes / No
5. Pain on squatting \_\_\_\_\_ Yes / No

Grade of Injury:

Grade 1: Pain after sport but not during or affecting sport

Grade 2: Pain during sport but not affecting sport

Grade 3: Pain during sport and affecting sport

Grade 4: Pain prevents all participation in sport

Current training history (Sport, hours per week)

Previous Sporting history (Sport, Years participated)

History of skin irritation with taping?

Any concern regarding the possibility of skin irritation?

**Appendix 5****ANTHROPOMETRICAL DATA SHEET**

DATE: \_\_\_\_\_

NAME: \_\_\_\_\_

SUBJECT CODE: \_\_\_\_\_

AGE: \_\_\_\_\_

WEIGHT (kg): \_\_\_\_\_

**SKINFOLDS (mm):**

Triceps: \_\_\_\_\_

Calf: \_\_\_\_\_

Biceps: \_\_\_\_\_

Thigh: \_\_\_\_\_

Subscap: \_\_\_\_\_

Abdomen: \_\_\_\_\_

Supra-iliac: \_\_\_\_\_

**GIRTHS (cm):**

Calf: \_\_\_\_\_

Above knee: \_\_\_\_\_

Sub-gluteal: \_\_\_\_\_

Forearm: \_\_\_\_\_

Mid-thigh: \_\_\_\_\_

**HEIGHTS (cm):**

Sub-gluteal - knee: \_\_\_\_\_

Stature: \_\_\_\_\_

## Appendix 6

### KIN COM AND EMG DATA SHEET

Subject name: \_\_\_\_\_ Code: \_\_\_\_\_

Kin Com test	EMG code No taping Order:		EMG code Placebo taping Order:		EMG code Medial taping Order:	
		VAS		VAS		VAS
Conc 1						
2						
3						
Ecc 1						
2						
3						
Isom max 5sec						
<b>Step Test</b>						

**Appendix 7**

**VISUAL ANALOGUE SCALE (VAS)**

