The effect of McConnell taping on knee biomechanics: What is the evidence?

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Declaration

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Abstract

This review aims to present the available evidence for the effect of McConnell taping on knee biomechanics in individuals with Anterior Knee Pain (AKP). Pubmed, Medline, Cinahl, Sportdiscus, Pedro and Science Direct electronic databases were searched from inception until September 2014. Experimental research into knee biomechanical or EMG outcomes of McConnell taping compared to no tape or placebo tape were included. Two reviewers completed the searches, selected the full text articles and assessed the risk of bias of eligible studies. Authors were contacted for missing data. Eight heterogeneous studies with a total sample of 220 were included in this review. All of the studies had a moderate to low risk of bias and compared taping to no tape and/ or placebo tape. Pooling of data was possible for three outcomes; average knee extensor moment, average VMO/VL ratio and average VMO-VL onset timing. None of these outcomes revealed significant differences. The evidence is currently insufficient to justify the routine use of the McConnell Taping technique in the treatment of Anterior Knee Pain. There is a need for more evidence on the aetiological pathways of Anterior knee Pain; level one evidence and studies investigating other potential mechanisms of McConnell taping.

(203 words)

Opsomming

Die objektief van hierdie resensie was om te bepaal wat die effekte van McConnell Patellar Vasbinding is op knie kinematika, kinetiek en spier aktivering in diegene met Voorafgaande Knie Pyn (VKP). Die navorsers het elektroniese databases soos Pubmed, Medline, Cinahl, Sportdiscus, Pedro en Science Direct, van aanvang tot September 2014, ondersoek. Eksperimenteel studie ontwerpe wat biomeganiese of EMG gevolge van McConnell Vasbinding vergelyk met geen vasbinding of placebo vasbinding, is ingesluit. Twee resente het die ondersoek voltooi, die volle tekse artikels gekies en die partydigheid risiko van die ingeslote studies, geskat. Skrywers is gekontak vir enige verlore data. Agt heterogeen studies uit ‘n totalle monster van 220 is in hierdie resensie ingesluit. Al die studies het ‘n gematigde tot laag risiko vir eensydigheid en vergelyk vasbinding met geen of placebo vasbinding. Data saamvoeging was moontlik vir drie uitslae, naamlik: gemiddelde knie ekstensor moment; gemiddelde VMO/VL ratio en gemiddelde aanval tydmeting. Geen gevolge het veelseggende verskille of afwykings vertoon. Tans is die bewys nie genoegsaam om die routiene gebruik van McConnell Vasbinding tegniek te regverdig nie in die behandeling van VKP. Meer bewyslewering op die etiologiese paaie van VKP; Graad een bewys en studies wat ander moontlike meganisme van Mc Connell Vasbinding ondersoek, is noodsaaklik.

(205 woorde)

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Abbreviations

ADLs-	Activities of Daily Living
AKP-	Anterior Knee Pain
CI-	Confidence Interval
CT-	Computed Tomography
EMG-	Electromyography
ITB-	Iliotibial Band
MD-	Mean Difference
MRI-	Magnetic Resonance Imaging
PFJ-	Patellofemoral Joint
PFJRF-	Patellofemoral Joint Reaction Force
PFPS-	Patellofemoral Pain Syndrome
RCT-	Randomised Controlled Trial
TFJ-	Tibiofemoral Joint
VAS-	Visual Analogue Scale
VL-	Vastus Lateralis
VMO-	Vastus Medialis Oblique

CHAPTER 1: INTRODUCTION

Anterior Knee Pain (AKP) is ‘a common symptom complex typically characterised by diffuse retropatellar or peripatellar knee pain’ (Clifford & Harrington, 2013). This pain is intensified by activities that increase the patellofemoral compressive force by loading the flexed knee joint (Witvrouw et al., 2014). It is the most frequently diagnosed knee condition in patients under the age of 50 and although prevalence is in the general unknown, the incidence has been reported to be 25-43% in sports injury clinics (Witvrouw et al., 2000 and Callagan & Selfe 2007). AKP is particularly common in adolescents, between the ages of 12 and 17 years (Rathleff et al., 2013) and may limit an individual’s ability to perform common activities of daily living (ADLs) such as stair climbing and prolonged sitting (Nunes et al., 2013). It can also cause significant prolonged or recurrent pain during repetitive high load activities such as running, jumping and squatting, thus limiting participation and performance in sport. AKP is a currently a problematic condition to treat as the underlying causes are not well understood. This makes rehabilitation difficult. It is thought to be multifactorial in origin (Aminaka & Gribble, 2008). It also has the tendency to become chronic, especially in active individuals, adding an additional aspect of complexity to the treatment (Collins et al., 2012).

1.1 Definitions and diagnosis of AKP

There are many definitions and synonyms for AKP. It is often used as an umbrella term for pathologies that cannot be classified as anything else, and therefore can include a variety of different pathologies. The term has been used interchangeably with patellofemoral pain syndrome, chondromalagia patellar, runners knee, patellofemoral joint dysfunction and patella arthralgia (Collins, Bisset, Crossley, & Vicenzino, 2012; Cook, Hegedus, Hawkins, Scovell, &

Wyland, 2010; Lake & Wofford, 2011; Nunes, Stapait, Kirsten, de Noronha, & Santos, 2013).Table 1 illustrates the range of definitions reported in systematic reviews.

Table 1: Definitions and synonyms for AKP

Crossley, Bennell, Green, & McConnell, 2001	PFPS AKP	An umbrella term used to encompass all anterior or retropatellar pain in the absence of other specific pathology. All pathologies that may manifest as anterior or retropatellar pain.
Harvie, O'Leary, & Kumar, 2011	PFPS	Diffuse retro/peripatellar pain, aggravated with activities which load the patellofemoral joint, such as climbing stairs, squatting, running, and prolonged sitting.
Aminaka & Gribble, 2005	PFPS	A condition presenting with anterior knee pain or pain behind the patella (retropatella). It is commonly experienced during running, squatting, stair climbing, prolonged sitting and long-sitting.
Cook, Mabry, Reiman, & Hegedus, 2011	Chondromalacia patella PFPS AKP	Old term used for PFPS. Anterior knee pain including the patella, but not including tibiofemoral or peripatellar structures. Anterior knee pain of more than 3 months duration, aggravated by sitting, squatting, stairs. All pain at the front of the knee.
Nunes, Stapait, Kirsten, de Noronha, & Santos, 2013	PFPS	In the absence of other intra-articular disorders, there is currently consensus that anterior knee pain, which limits activities of daily living that demand knee flexion such as climbing and descending stairs, squatting or remaining seated. Synonyms include chondromalacia patellae, patella arthralgia, patella pain
Lake & Wofford, 2011	Runners knee PFPS	Synonym for PFPS as it is common in runners and other endurance athletes. AKP characterised by diffuse anterior knee pain, aggravated with specific activities that heighten the compressive loading forces across the patellofemoral joint including ascending and descending stairs, squatting, and prolonged sitting.
Collins, Bisset, Crossley, & Vicenzino, 2012	AKP	Synonym for PFPS. Chronic musculoskeletal overuse condition of the knee that affects an individual's ability to perform routine daily activities such as stair ambulation, walking and running, and thus impacts on work-related activities and participation in physical activity.
Barton et al., 2012	PFPS	AKP of insidious onset defined as the presence of pain in the retropatellar or peripatellar region during tasks that increase patellofemoral joint loading, such as walking, running, negotiating stairs, squatting, prolonged sitting and kneeling. Anterior knee pain or retro-patellar pain in the absence of other specific pathology
Em et al., 2008	PFPS	Retropatellar pain (behind the kneecap) or peripatellar pain (around the kneecap) when ascending or descending stairs, squatting or sitting with flexed knees.
Prins & van der Wurff, 2009	PFPS	The remainder of knee pain cases after intra-articular pathologies, patella tendonopathies, peripatellar bursitis, plica syndrome, Sinding-Larsen Johnson and Osgood-Schlatter have been excluded.
Callaghan & Selfe, 2012	PFPS AKP	The clinical presentation of knee pain related to changes in the patellofemoral joint. Pain at the front of the knee, separate from arthritis.

		Gradual onset of knee pain with none of the features associated with other knee injuries or diseases. Pain at the front of the knee, used synonymously with PFPS.
Waryasz & McDermott, 2008	PFPS AKP	A variety of pathologies or anatomical abnormalities leading to a certain type of AKP. Broader term for all pathologies causing pain at the front of the knee, including referred pain from the lumbar spine or hip.
Heintjies et al., 2008	PFPS Retropatellar pain	A common compliant in adolescents and young adults, most frequently characterised by diffuse peripatellar and retropatellar localised pain, typically provoked by ascending or descending stairs, squatting and sitting with flexed knees for prolonged periods of time. Retropatellar pain in which no cartilage damage is evident. A self-limiting condition of the knee , that includes cartilage damage.
Lankhorst, Bierma-Zeinstra, & van Middelkoop, 2012	PFPS AKP	A condition of anterior knee pain. Pain in or around the patella. This pain increases after prolonged sitting, squatting, kneeling, and stair climbing. Covers all problems related to the anterior part of the knee.

Anterior Knee Pain can be defined as retropatellar or peripatellar pain, of more than three months duration, in the absence of intra-articular pathology, that is aggravated by activities that load a flexed knee joint (Crossley, Bennell, Green, & McConnell, 2001; Harvie, O'Leary, & Kumar, 2011; Nunes et al., 2013; Prins & van der Wurff, 2009). The diagnosis of AKP is made based on the definition as well as the exclusion of other pathologies. These include osteoarthritis, rheumatoid arthritis, patella fractures, patella subluxation and dislocation, fat pad impingement or bursitis and growth disorders such as Osgood-Schlatter, intra-articular pathology, patellar tendinitis, or referred pain from the lumbar spine or hip (Cook et al., 2012; Lake & Wofford, 2011; Lankhorst, Bierma-Zeinstra, & van Middelkoop, 2012b; Selfe, 2012; Sweitzer, Cook, Steadman, Hawkins, 2010; Waryasz & McDermott, 2008).

1.2 Anatomical considerations of AKP:

Many anatomical and biomechanical dysfunctions have been hypothesised to play a role in the development of AKP. However, a direct relationship between structural abnormalities has not been established (Witvrouw et al., 2014). The function of the patella is to protect the tibiofemoral joint (TFJ) and to improve the efficiency of knee flexion. Stability of the patella is provided by a combination of structures around the patella including the quadriceps tendon, the patella tendon, the medial reticulum and the medial retinaculum. It is believed that patella instability occurs if patella stabilisers are weak or malaligned and this has been correlated to the incidence of patellofemoral pain, although causation has not been established (Witvrouw et al., 2000). A variety of local factors may contribute towards AKP (Witvrouw et al., 2014). Bony local factors related to the PFJ may include joint geometry: shallow trochlear groove, patella alta and an increased sulcus angle (Amis, 2007). Other local structures that could contribute towards pain include the infrapatellar fad pad, bone marrow lesions, effusions and synovitis, however the evidence supporting this is limited (Dragoo et al., 2012; Zhang et al., 2011).

Neuromuscular control dysfunction and imbalance of the quadriceps force vector, may result in an inability of the quadriceps to centralise the patellar in the trochlear groove. Some EMG studies have suggested that VMO is less active and that the VMO/ VL onset timing is altered in subjects with AKP (Cowan et al 2001: 2002). Other studies show not differences in quadriceps activation ratios and VMO activity between the pain group and controls (Keet et al., 2007). Other potential muscular contributing factors include decreased hip muscle

strength, especially abductors, as well as tightness of the hamstrings, quadriceps, ITB, gastrocnemius and soleus muscles (Waryasz & McDermott, 2008).

It has also been suggested that an abnormal Q angle heightens the risk of developing AKP by increasing patellofemoral pressure (Emami, Ghahramani, Abdinejad, Namazi, 2007). According to systematic review by (Smith, Hunt, & Donell, 2008) on the validity and reliability of this as a clinical test the evidence to support this is poor. There is conflicting evidence and a lack of standardisation of the measurement of the Q angle. Therefore, clinical usefulness of this is unclear.

1.3 Risk factors for Anterior Knee Pain:

A systematic review by Lankhorst, Bierma-Zeinstra & Van Middelkoop (2012), investigated risk factors for AKP. Seven prospective studies with a total of 243 participants with AKP were included. Only one biomechanical risk factor was identified as highly correlated to the development of AKP. This biomechanical risk factor was the knee extensor strength and was identified in two studies (Boiling et al., 2010; Milgrom & Finestone, Eldad, & Shlamkovitch, 1991). Both studies found that knee extensor strength was decreased in subjects with patellofemoral pain compared to controls. This suggests that improving knee extensor strength and mechanics might be an important aspect of both prevention and rehabilitation for this condition. However, these two cohort studies investigated midshipmen and infantry recruits and therefore the results might not be generalisable to all AKP subjects.

In the aforementioned systematic review, female gender, was also identified as a likely risk factor. Some literature suggests that females with AKP employ altered hip and knee kinematics across a variety of dynamic activities including single leg squatting, single leg

jumping, running and stair descent (Wilson & Davis, 2007; Grenholm et al., 2009). However, there is conflicting evidence showing that femlaes with AKP do not have altered hip and knee kinematics during stair descent (Bolgla, Malone, Umberger, & Uhl, 2008). In addition,it is not clear whether these findings can be generalised to males with AKP.

The other evidence included in the review was from single studies. These risk factors included psychological outcomes, physical fitness, joint angles, posture patellar mobility, vertical ground reaction force, plantar pressure and electromyographic onset timing of VMO and VL. (Duffey, Martin, Cannon, Craven, & Messier, 2000; Study, Witvrouw, Lysens & Bellemans, 2000; Thijs, Van Tiggelen, Roosen, De Clercq, & Witvrouw, 2007; Van Tiggelen, Cowan, Coorevits, Duvigneaud, & Witvrouw, 2009). There is insufficient evidence to show that any of these risk factors are likely to be linked to the development of AKP. Therefore, it is clear that more research on the risk factors for AKP is needed and prospective studies are imperative.

1.4 Current treatment for Anterior Knee Pain

There is agreement among recent reviews that conservative approaches are the preferred choice of treatment for AKP (Collins et al., 2012; McCarthy & Strickland, 2013).Surgical options such as distal realignment of the extensor mechanism, lateral retinacular release or debridement may be considered when conservative methods have failed (McCarthy & Strickland, 2013).

Collins et al., (2012) summarised the literature on conservative treatment options. According to the authors (Collins et al., 2012), there is no conclusive or convincing evidence to support individual treatment strategies and until there is, a six week multimodal approach including a

combination of manual therapy, exercise, lower limb stretches, patellar taping and education should be used. Following this period, interventions such as foot orthoses and acupuncture might be beneficial (Collins et al. 2008; Jensen, Gøthesen, Liseth & Baerheim, 1999). The review highlighted the lack of high-quality randomised controlled trials to support individual conservative interventions. It is apparent that there is no conclusive evidence for individual treatment approaches, and we are still unclear on how best to manage this condition.

1.5 Description of McConnell taping:

One of the most popular interventions used in the treatment of AKP is patellar taping. Different methods of taping have been used and the theory behind these taping strategies varies. Some clinical techniques include bracing, tendon straps and kinesiology taping. The most frequently used technique is the rigid McConnell taping technique, introduced by Jenny McConnell in 1986 (McConnell, 1986). This theory is hypothesised to decrease pain and alter biomechanics by addressing one of four components of malalignment that may need to be corrected. These are medial glide, medial tilt, anterior tilt and rotation (Crossley, Cowan, Bennel & McConnell, 2000). It is therefore aimed at targeting the local contributing factors of patellofemoral pain.

According to McConnell the taping should provide immediate pain relief and will therefore enable the individual to perform pain free quadriceps exercises (McConnell, 1986; Crossley et al., 2000). In reality the mechanism and effectiveness of McConnell taping remains unclear. Assuming that McConnell taping does result in immediate pain relief, it is still unclear whether the effects are due to neuromuscular, biomechanical, proprioceptive or even placebo mechanisms (Aminaka & Gribble, 2008).

The technique has the potential to be clinically useful as it is an inexpensive, time efficient and practical intervention. Therefore, the mechanisms and effectiveness need to be established.

1.6 Problem statement

Anterior Knee Pain is a common disorder, neither understood nor well-managed. Clinically, McConnell taping is considered to be a standard treatment option for AKP (Wilson, Carter, Phys, & Thomas, 2003). However, there is insufficient evidence to support the proposed effects and mechanisms. The technique was developed in 1986 and is still routinely taught to students and included in sports medicine textbooks (Brukner & Khan, 2012; Hudson & Small, 2011). It is therefore important to know whether it is effective or if its routine use is outdated.

1.7 Aims

The main aim of this thesis is to ascertain what the evidence base is for McConnell taping technique in the treatment of AKP by describing the effects on biomechanics and muscle activation.

1.8 Objectives:

- To determine if patellar taping results in immediate differences in tibiofemoral and patellofemoral kinematics and kinetics using 3-Dimensional motion analysis.
- To determine the effects of McConnell taping on muscle activation around the patella, measured using electromyography.
- To synthesise and critically appraise the literature on the effect of taping on the anatomy and biomechanics of the knee complex.

CHAPTER 2: MANUSCRIPT

Title:

The use of McConnell taping to correct abnormal biomechanics and muscle activation patterns in subjects with Anterior Knee Pain: A systematic review

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This manuscript was submitted to the Journal of Sports Biomechanics. The journal guidelines are included as Appendix F.

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I affirm that I have no affiliation or involvement with any commercial organisation that has a direct financial interest in any matter included in this manuscript, except as disclosed in an attachment and cited in the manuscript any other conflict of interest (i.e., personal associations of involvement as a director, officer, or expert witness) is also disclosed in an attachment. The funding for this research project was provided by the National Research Foundation (NRF).

KEYWORDS:

Patellar Taping, Patellofemoral Pain Syndrome, Kinematics, Kinetics, Electromyography

2.1 INTRODUCTION

2.1.1 Description of condition

Anterior Knee Pain (AKP) is 'a common symptom complex typically characterised by diffuse retropatellar or peripatellar knee pain exacerbated by activities that load the flexed knee joint' (Clifford & Harrington, 2013). Such activities include ascending or descending stairs, squatting, walking, running or sitting for prolonged periods of time (Nunes, 2013). Furthermore, AKP is a chronic condition as the duration is typically more than three months and can continue to be a problem for years (Cook et al., 2010).The diagnosis of AKP is complex and can only be made when other pathologies such as intra-articular pathologies, patella tendonopathies, peripatellar bursitis, plica syndrome, Sinding-Larsen Johnson, Osgood-Schlatter and referred pain from the lumbar spine or hip have been ruled out (Prins & Van der Wurff, 2009; Waryasz & McDermott, 2008).

2.1.2 Proposed causes of AKP

Despite prolific literature the aetiology of AKP remains unclear. However, it is suggested that the cause of AKP involves increased Patellofemoral Joint (PFJ) contact stress. This is mainly caused by knee flexion during dynamic weight-bearing activities (Brechter & Powers, 2002). Factors influencing the load on the PFJ can be intrinsic or extrinsic. Extrinsic factors that might cause overload of the PFJ include increased training volume, an increase in speed, increased training on stairs or hills. Factors such surfaces, footwear, and body mass or anthropometry might also need to be considered (Brukner & Khan, 2012). Intrinsic factors could also influence the distribution of PFJ load. The distribution of load is conceptualised as movement of the patella within the femoral trochlear otherwise known as patellar tracking (Ireland, Wilson, Ballentyne & Davis, 2003). It is proposed that individuals with PFPS have

lateral displacement of the patellar within femoral trochlear (MacIntyre, 2006). Intrinsic factors can be remote or local. Remote factors believed to influence patellar tracking include an increase in femoral rotation, increased valgus stress at the knee, increased tibial rotation, increased subtalar rotation and inadequate flexibility. Local factors such as patella position, soft tissue contributions and neuromuscular control of the vastii are hypothesised to contribute to abnormal tracking (Brukner & Khan, 2012). These factors are frequently targeted with therapeutic interventions for AKP (Lankhorst et al., 2012).

2.1.3 Description of taping intervention

The original taping intervention for the treatment of AKP was developed by Jenny McConnell in 1986 in her landmark paper entitled “The Management of Chondromalacia Patellae: A Long Term Solution” (McConnell, 1986). The rigid taping technique, also known as McConnell taping is still frequently used in clinical practice (Campolo, Jenie, Dmochowska, Scariah, & Varughese, 2013). According to McConnell there are four different components of malalignment that may need to be corrected; medial glide, medial tilt, anterior tilt and rotation. The choice of technique depends on how the patient presents and more than one component might need to be included (Crossley, Cowan, Bennel & McConnell, 2000). According to McConnell, taping should provide immediate pain relief during functional activities such as squatting. If the pain has not been reduced following taping, the method of taping used should be altered and pain during functional activity should be reassessed. As the quadriceps are inhibited by pain, once pain relief has been achieved it should enable the individual to perform pain free quadriceps exercises and functional activities (for example squatting and stair climbing or squatting) Therefore, the combination of taping and exercise could also lead to strengthening of the quadriceps (McConnell, 1986; Crossley et al., 2000). However, the

precise mechanism of patellar taping remains unclear. Reported expected effects could be due to neuromuscular, biomechanical, proprioceptive or placebo mechanisms (Aminaka et al., 2008).

2.1.4 Proposed mechanisms of taping

McConnell's taping theory argues that an active medial patella stabiliser, the Vastus Medialis Oblique (VMO) muscle, could be activated through taping, thereby stabilising the joint in opposition to the lateral pull of the remainder of the quadriceps muscle (McConnell, 1986). Another reported effect of patellar taping is to reposition the patella within the femoral trochlea groove. This alters the PFJ contact load and joint reaction force, thereby reducing pain (Herrington, 2000). There is limited evidence suggesting that patellar taping alters the biomechanics in subjects with Anterior Knee Pain. An MRI study by Pfeifer et al. (2004), found that taping induces medial glide of the patellar when the knee is in passive flexion. However, this may not be evident during functional activities when individuals with AKP typically experience pain. Salsich et al. (2002) suggested that patellar taping increased knee flexion angles and knee extensor moments compared to no taping in an anterior knee pain population during stair ascent and descent. Due to conflicting evidence of EMG and insufficient evidence of patella biomechanics, some authors propose proprioceptive somatosensory mechanism of taping (Selfe et al., 2011).

2.1.5 Current literature on the effects of taping for Anterior Knee Pain

A systematic review by Callagan & Selfe (2012), questions the assumption that patellar taping results in immediate significant pain reduction. The review included five RCTs and described the effects of a McConnell taping intervention on pain, function, activities of daily living and quality of life in individuals with AKP. A meta-analysis done on four of these studies for the

Visual Analogue Scale (VAS) for pain showed no statistically or clinically significant difference between patellar taping and non-taping. This suggests that the pain relieving effects of patellar taping might be over-emphasised. Pooling of the other outcome data; function, activity levels and quality of life, was not possible as they were from individual studies and the results were conflicting.

A critical review by Overington, Goddard and Hing in 2004, reviewed some of the objective outcomes of patellar taping such as patella position, EMG outcomes and strength. Twenty one studies were included. Ten studies looked at McConnel taping and eleven looked at other taping methods. For all three of the outcomes the results were conflicting and no conclusive recommendations could be made. This could due to the review process not being systematic. In addition the results were only represented descriptively and the specific outcomes were not standardised, making them difficult to compare. A systematic review of the literature is needed in order to ensure the all of the relevant evidence has been analysed before recommendations can be made.

2.1.6 Why is it important to do this review?

To our knowledge there have been no systematic reviews with meta-analyses done to investigate the effects of taping on objective outcomes such as biomechanics and muscle activation. Following the conflicting results of Callagan and Selfe's review, we need to ascertain whether there is a biomechanical justification for the continued use of patellar taping techniques. Biomechanical abnormalities and muscular dysfunction are commonly reported as aetiological pathways of AKP (Juhn, 1999).The proposed underlying mechanism of effect of taping involves its ability to "correct" abnormal knee biomechanics. Therefore the effect of taping on biomechanics must be understood. Taping is an appealing intervention, as it is cost-

effective and time efficient. It is also versatile and can be done in any environment and setting. If effective in the short and long term, this will be clinically useful. However, if it is not effective or has no scientific underlying rationale, it forces one to question why this technique, developed in 1986, is still routinely used today and advised for treating AKP in current sports medicine textbooks (Brukner & Khan, 2012; Hudson & Small, 2011). As there is a large body of literature on the topic, it will be useful to synthesise the evidence on the biomechanical outcomes of patellar taping as this is a proposed underlying mechanism. This will serve to establish what has already been done, to address the limitations and recommendations of previous studies and to identify important gaps that will contribute to the field of knowledge.

Therefore, the aim of this review is to systematically appraise the evidence to determine if patellar taping results in an immediate change in tibio-femoral and patellofemoral kinematics and kinetics and lower extremity muscle activation (electromyography) in individuals with AKP.

2.2 METHODOLOGY

The study protocol was approved by the Health Research Ethics Committee of Stellenbosch University in Cape Town, South Africa. The authors certify that they have no affiliations with or financial involvement in any organisation or entity with a direct financial interest in the subject matter or materials discussed in the article.

2.2.1 Criteria for considering studies for this review (inclusion and exclusion criteria)

2.2.1.1 Types of studies

Randomised controlled trials (including cross-over randomised trials) and randomised single subject experimental designs were eligible for inclusion. All other quantitative and qualitative research was excluded. Only English studies were included in this review.

2.2.1.2 Types of participants

The review included studies on any individuals diagnosed with AKP which could include any of the many synonyms associated with this condition (Patellofemoral pain syndrome, patellofemoral joint dysfunction, retropatellar pain, patella malalignment syndrome, chondromalacia patella) as long as these studies conformed to the diagnostic criteria and excluded pathologies attributed to sources other than the patellofemoral joint (PFJ). The studies included in this review needed to adhere to the diagnostic criteria most frequently used in previous systematic reviews (Cook et al., 2012; Lake & Wofford, 2011; Lankhorst et al., 2012b; Selfe, 2012; Sweitzer, Cook, Steadman, Hawkins, 2010; Waryasz & McDermott, 2008).

Based on these studies, the knee pain participants in the included studies should comply with the following diagnostic criteria: pain at the front of the knee or retropatellar pain that is aggravated by two or more of the following functional activities: squatting, prolonged sitting, ascending or descending stairs, kneeling, lunging or jumping. Males and females were included. Studies that included participants over the age of 40 were excluded in order to rule out osteoarthritis as a differential diagnosis. Studies that did not describe the diagnostic criteria used for the inclusion of participants were excluded.

2.2.1.3 Types of interventions

Studies investigating any type of McConnell taping intervention compared to a placebo or no taping were included. Studies using other taping methods such as K-tape were excluded. Studies using taping in combination with other interventions (multimodal treatment) were excluded. Studies investigating taping compared to another intervention were excluded.

Multimodal treatment interventions, not assessing effects of individual treatment strategies were excluded. Studies that described other disorders of the knee such osteoarthritis, patella subluxation or intra-articular pathology were excluded.

2.2.1.4 Types of outcomes

The primary outcomes of interest for this review were the biomechanical parameters of the lower extremity.

1. EMG:

   We considered EMG studies with outcomes including but not limited to onset of muscle activation, average amplitudes, maximum amplitudes, timing of onset and VMO/VL ratios. Fine wire and surface EMG studies were added.

2. Kinematics:

   Studies that used 3D motion analysis to acquire lower extremity joint kinematics were included. We included studies reporting on patellofemoral joint kinematics such as lateral, displacement, tilt and rotation measurements, but tibiofemoral joint kinematics were also included in this review. Magnetic resonance imaging (MRI), computed tomography (CT) scan and x-ray studies were excluded since functional movement is not possible during these investigations.

3. Kinetics:

   Studies describing kinetic outcomes such as moments and ground reaction forces of the tibiofemoral joint or patellofemoral joint were included.

   Studies investigating other outcome measures such as pain, function, proprioception and strength measured without any biomechanical outcome measures were excluded.

2.2.1.5 Timing of outcome assessment

Outcomes measuring effects of taping immediately post intervention (short-term) were considered.

2.2.1.6 Activities

Outcomes measured during functional activities that commonly aggravate PFPS were considered. These activities included but were not limited to gait, stair climbing, running, squatting and jumping.

2.2.2 Search strategy

A comprehensive search was conducted in September 2014 in all accessible library databases of published research reports available at the Stellenbosch University Medical

Library. The following databases were searched up to June 2014: PubMed, Ebscohost (MEDLINE, CINAHL, SportDiscuss), PEDro, SCOPUS, Science Direct. No date limit was applied to any of the databases. A number of key words were applied to each database's search tool to narrow the search and to develop the most precise strategy for that database. Only English articles were included. The same key search terms were used for all databases with the appropriate truncation and Boolean operators (such as AND and OR).

The key terms used for the search string were taping AND (anterior knee pain OR patellofemoral pain syndrome) AND (Kinematics OR kinematics OR electromyography) AND (effect* OR outcome* OR result*) AND (trial*). The same approach was used for all searches adapted as necessary according to specifics for that database. MeSH terms were used for "Anterior Knee Pain" in search engines, such as Pubmed, that made use of that function. Pearling (checking the reference lists of identified studies) and hand searching (journals predating electronic databases or not appearing in electronic databases) were also conducted to increase the search base. Secondary searching was undertaken, when more detail of a study described in the systematic review was required, especially when articles within the systematic reviews contained more detailed definitions for the various terms described. Google Scholar was also examined for any grey literature that was not represented within the database.

The searches were conducted by the researcher (DL) and an information specialist (WP) with experience in systematic review searches (see Appendix A).

2.2.3 Data collection and analysis

This review was done according to the Prisma Guidelines. One reviewer (DL) screened the titles and abstracts of all initial hits and independently screened all potential full text papers according to the eligibility criteria described above. A second reviewer (QL) was consulted when necessary. The same two reviewers retrieved the full texts of all potentially relevant articles and then screened them independently using the same criteria in order to determine the eligibility of the papers for inclusion in the review.

2.2.4 Methodological appraisal

The Cochrane Collaboration's recommended risk of bias assessment tool (Appendix B) was used to assess the risk of bias of the included studies. A specific aspect of the study is targeted by individual entries in the tool and a "risk of bias" table within the tool accounts for a judgement and support of judgement for each entry. The risk of bias is recorded as "low", "high" or "unclear", the latter highlighting either lack of information or uncertainty with regard to the potential for bias. When the tool is used for clinical trials, as in the current study, biases are broadly categorised into five categories; as selection bias, performance bias, detection bias, attrition bias, reporting bias and other biases that do not fit into these categories. The reviewer referred to the user guidelines to assist in interpretation of the Scale. Two randomly selected papers were reviewed by a second reviewer (SVN) and discrepancies in the results were discussed.

2.2.5 Level of evidence

The Department of Medicine at McMaster University has developed guidelines for hierarchies of evidence that vary depending on which study design best answer a specific type of clinical question. These guidelines can be seen on their

website.(http://fhs.mcmaster.ca/medicine/residency/halfday_ebm.htm). In this review, an intervention is being investigated. Therefore, the evidence was graded according to the suggested McMaster guidelines for the hierarchy of evidence most appropriate for making treatment designs. The evidence levels are presented below (Figure 1).

A hierarchy of strength of evidence for treatment decisions:

- **N of 1 trial**
- **Systematic reviews of randomised trials**
- **Single randomised trial**
- **Systematic review of observational studies addressing patient-important outcomes**
- **Single observational study addressing patient-important outcomes**
- **Physiologic studies (such as studies of blood pressure, cardiac output, exercise capacity, bone density)**
- **Unsystematic clinical observations**

Figure1: McMaster hierarchy of evidence for intervention studies (McMaster University, 2014)

For this review we considered Level 1 (single subject designs) and Level III (single randomised trials). We have already established that there is not a systematic review (Level II) which addressed this research question during a preliminary search.

2.2.6 Data management and extraction

A purpose built MS Excel sheet was used for data management. A different sheet was used for each database and the information regarding search terms used number of initial hits, number of studies excluded on title, number of duplicates, number of studies excluded on abstract, number of studies excluded on full text, number of included studies, references of

included studies and additional notes (including pearling) were entered into the different columns.

Data from the included studies were then entered into another Excel spreadsheet based on the Cochrane Extraction Form format. Authors were contacted for missing trial data, methodology and additional information required. Data was extracted into purpose-built MS Excel sheets from each relevant included study on author, title, aims of study, year of publication, study design, sample size, sample description (age, gender, height, weight, duration of symptoms), diagnostic criteria, methods, outcome measures, results, conclusion and additional notes. There were three different sheets used for different outcomes; kinematics, kinetics and electromyography.

2.2.7 Data synthesis and analysis

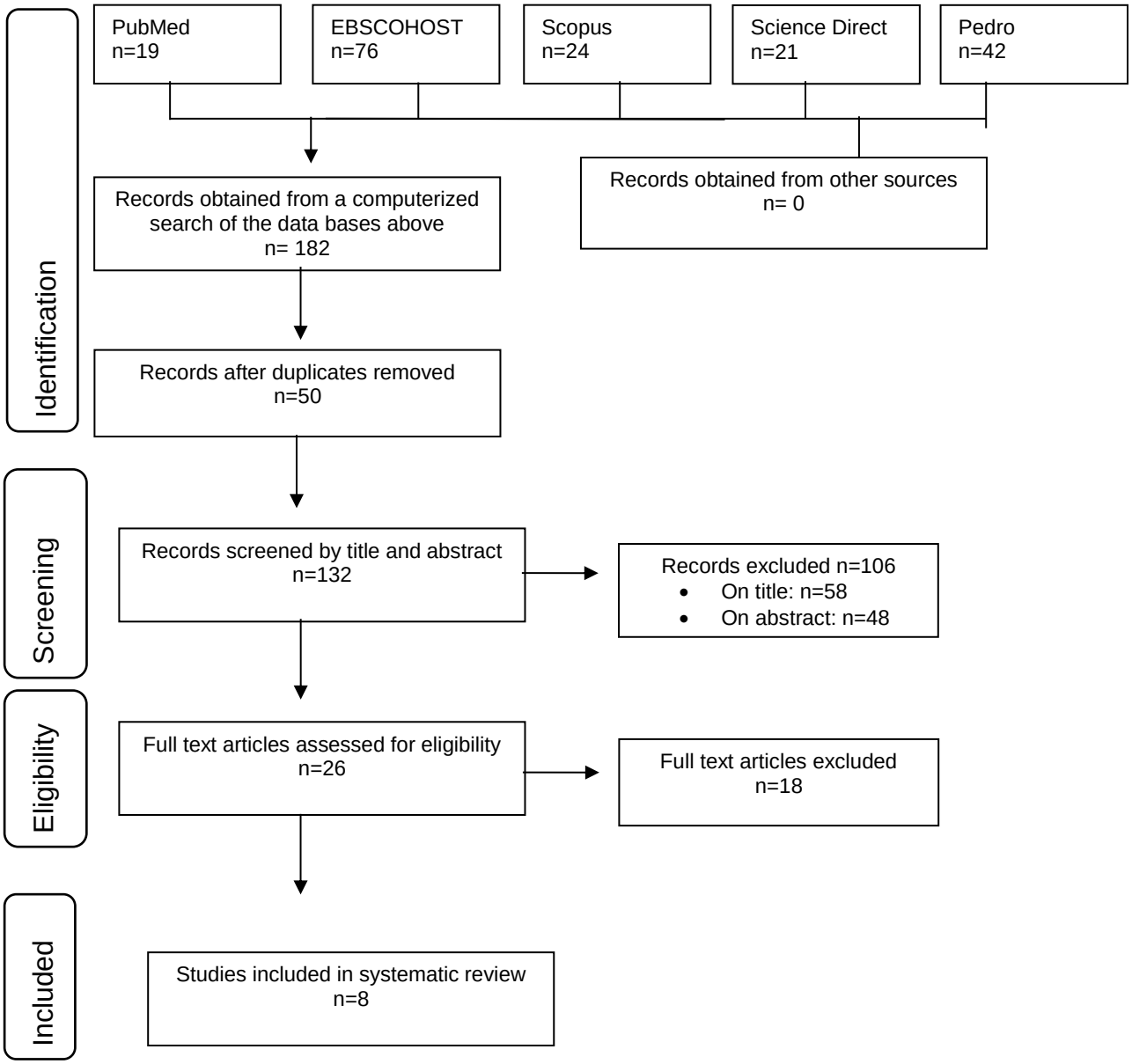
We extracted and analysed the data of subjects with AKP only. For all eligible studies, the number of subjects with AKP, demographics and pain characteristics were described narratively using tables or narrative summaries.

For the knee biomechanical outcomes, we extracted means and standard deviations (SDs) of each outcome where available, to allow effect size (ES) calculations. A random effects model in Revman version 5.3 was used to calculate mean differences (as the measure of effect) and 95% confidence intervals. These values were presented as forest plots. A meta-analysis was conducted for knee biomechanical outcomes which more than one study evaluated and outcomes for the study were homogeneous.

We also extracted pain outcomes for studies that took Visual Analogue Scale (VAS) pain rating before and after the taping intervention.

2.3. RESULTS

The initial search based on the search words described above yielded a total of 182 hits. Following the application of the inclusion and exclusion criteria to the titles, 58 studies were excluded and 50 duplicates were removed reducing the total number of potential studies for inclusion to 110. The main reason for exclusion by title was that the studies were looking at conditions other than PFPS. After abstracts were read, 48 studies were excluded. The primary reason for excluding these studies was because the intervention used was not taping; because the study was not a journal article or taping was done on asymptomatic participants. After reading the 26 full texts that were still eligible, the number of studies to be included in this systematic review was reduced to 8. The main reasons for excluding full texts included incorrect outcome measures and incorrect study design (not a randomised controlled trial). Results of the search strategy can be seen in Figure 2.



Abbreviations: n= total number

Figure 2: Prisma guidelines for literature search

2.3.1 General description of the studies reviewed

2.3.1.1 Study population

The number of participants in each study varied from 14-40. The total sample was n=220. In the eligible studies, 130 subjects had AKP and the mean sample size was n=27.5. Most of the studies included males and females. However one study included females only (Powers et al., 1997). A sample description of the eight eligible studies can be seen in Table 2. The sample sizes, ages of participants, anthropometrics and study settings appear similar.

Table 2: Sample size and demographic information

	Sample size (n)			Gender (F/M)		Mean Age (yr) (SD)		Mass (kg) (SD)		Height (m) (SD)		Study setting
	Total	PFPS	CON	PFPS	CON	PFPS	CON	PFPS	CON	PFPS	CON	
Mostamand, Javid et al., 2011.	36	18	18	11M 7F	11m 7F	27.9 (6.3)	26.4 (4.9)	71.5 (9.5)	71.6 (11.1)	1.71(0.06)	1.72 (0.08)	Motion Analysis Laboratory Queen Mary University of London, UK
Cowan, Sallie et al., 2002.	22	10	12	3M 7F	4M 8F	22.7 (8)	19.5 (1.4)	59.3 (10.1)	60.8 (8.1)	1.67(0.96)	1.7 (0.15)	Motion Analysis Laboratory University of Melbourne, Australia
Aminaka, Naoko; Gribble, Phillip, 2008.	40	20	20	8M 12F	8M 12F	20.3 (1.87)	21.25 (2.67)	71.57(14.04)	70.91 (11.41)	1.71 (0.12)	1.72 (0.876)	Motion Analysis Laboratory University of Toledo, Ohio, USA
Keet, Janet et al., 2007.	35	15	20	4M 11F	7M 14F	29.1 (5.1)	29.4 (4.6)	65.2 (9.6)	64.4 (11.1)	DNR	DNR	Motion Analysis Laboratory Sport Science Institute, Cape town, South Africa
Mostamand, Javid et al., 2010.	36	18	18	11M 7F	11M 7F	27.9 (6.3)	26.4 (4.9)	71.5 (9.5)	71.6 (11.1)	1.71 (0.59)	1.72 (0.75)	Motion Analysis Laboratory Queen Mary University of London, UK
Ernst, G P et al., 1999.	14	14	N/A	14F	N/A	24.4 (5.8)	N/A	66.5 (12)	N/A	1.73 (0.07)	N/A	Motion Analysis Laboratory University of Virginia, USA
Cowan, S M et al., 2006.	22	10	12	DNR	DNR	23.0 (8.0)	19.5 (1.4)	59.3 (10.1)	60.8 (8.1)	1.67 (0.10)	1.71 (0.11)	Motion Analysis Laboratory University of Melbourne, Australia
Powers, C M et al., 1997.	15	15	N/A	15F	N/A	26.5 (7.2)	N/A	65.1 (8)	N/A	1.64 (0.05)	N/A	Ranchos Los Amigos Pathokinesiology Laboratory, Downey, California, USA

2.3.1.2 Study information

A common aim among all studies was to determine whether McConnell taping has an effect on a biomechanical outcome in subjects with AKP. However, there was significant heterogeneity amongst the studies included in this review. Four of the included studies investigated EMG, two studies looked at kinematics and two looked at kinetics. Six of the studies had an asymptomatic control group and two used a single group design. The study designs were all experimental, with the majority being randomised cross-over and repeated measures designs. The functional activities also varied, with step descent and single legging squatting being the most common activities tested. A description of the study aims as well as procedures can be seen in Table 3.

Table 3:

Study	Study Aim	Design	Outcome of interest	Functional activity
Mostamand, Javid et al., 2011.	To evaluate EMG activity of vastus medialis and vastus lateralis following the application of patellar taping during a functional single leg squat.	Randomised cross-over, 2 group	EMG Ratio of VM: VL VL amplitudes VM amplitude VMO-VL onset (ms)	Single leg squat
Cowan, Sallie et al., 2002.	To examine the effect of patellar taping on the onset of electromyographic activity of vastus medialis obliquus relative to vastus lateralis in participants with and without patellofemoral pain syndrome.	Randomised within subject.	Electromyographic onset of VMO and VL	Step descent
Aminaka, Naoko Gribble, Phillip, 2008.	To evaluate the effects of patellar taping on sagittal plane hip and knee kinematics, reach distance, and perceived pain level during the Star Excursion Balance Test (SEBT) in individuals with and without PFPS.	Repeated-measures design with 2 within-subjects factors and 1 between-subjects factors.	Sagittal-plane hip and knee kinematics	Single leg squat with reach
Keet, Janet et al., 2007.	To examine whether patellar taping does decrease pain, increase quadriceps strength and enhance neuromuscular recruitment.	Placebo-controlled clinical trial	EMG amplitudes VMO, VMO/VL ratio	Step descent
Mostamand, Javid et al., 2010.	To measure sagittal plane knee moments and PFJRF, after application of tape in patients with PFPS	Randomised cross-over, 2 group	Sagittal plane knee moments and PFJRF	Single leg squat
Ernst, G P et al., 1999.	To examine the effect of McConnell patellar taping on single-leg vertical jump height and knee extensor moment and power during a vertical jump and lateral step-up.	Single group, experimental repeated measures	Maximal knee extensor moment	Single leg vertical jumps and lateral step ups
Cowan, S M et al., 2006.	To investigate the effect of patellar taping on the amplitude of electromyographic activity of vasti activation in subjects with and without patellofemoral pain.	Randomised cross-over, 2 group	EMG amplitude of the VMO and VL	Ascending and descending stairs
Powers, C M et al 1997.	To assess the influence of patellar taping on gait characteristics and joint motion in subjects with patellofemoral pain.	Randomised cross-over, 1 group	Sagittal plane knee kinematics	Gait, stair descent, ramp descent

2.3.2 Methodological quality appraisal

The Cochrane Collaboration's risk of bias scores can be seen in Figure 3. It is worth noting that studies that compared taping and no taping without a placebo taping intervention were judged as having an "unclear risk" for allocation concealment and blinding, as blinding is not possible in these situations. The studies that did not include a placebo taping invention were also judged as having a high risk of "other bias" as the risk of a placebo effect was high. Most of the studies were judged as having a "low risk" of attrition bias as there were no drop outs. However, one study had missing outcome data. (Powers et al., 1997) did not report any measures of variability for the kinematic outcomes.

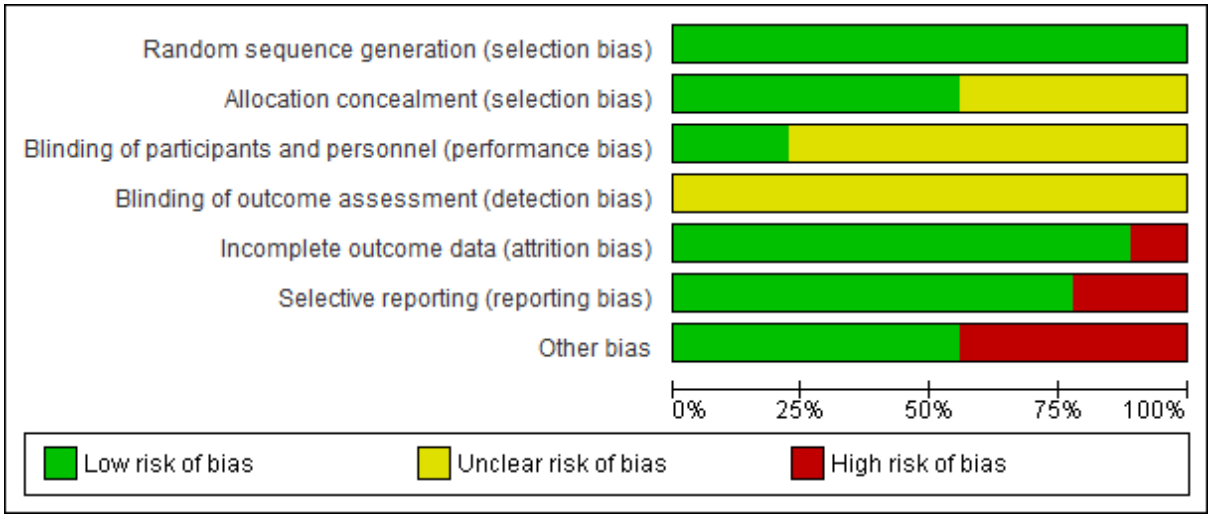


Figure 3: Cochrane Collaboration's risk of bias assessment tool

2.3.3 Diagnostic criteria

Table 4 outlines the key diagnostic criteria used by the eligible studies to determine which participants were eligible to take part. Eligible studies used these criteria to determine study inclusion and exclusion criteria.

Table 4: Diagnostic criteria for AKP

Key inclusion and exclusion criteria	Mostamand et al., 2011	Cowan et al., 2002	Aminaka et al., 2008	Keet et al., 2007	Mostamand et al., 2010	Ernst et al., 1999	Cowan et al., 2006	Powers et al., 1997
Clear definition of location of pain was reported	✔	✔	✔	✔	✔	✔	✔	X
Age less than 40	✔	✔	X	X	✔	X	✔	X
Aggravated by the following:								
Prolonged sitting	✔	✔	✔	✔	✔	X	✔	✔
Stair climbing	✔	✔	✔	✔	✔	✔	✔	✔
Squatting	✔	✔	✔	✔	✔	✔	✔	✔
Running	✔	✔	✔	X	✔	✔	✔	✔
Kneeling	✔	✔	✔	X	✔	✔	✔	X
Hopping	✔	✔	X	X	✔	X	✔	X
Diagnosis was confirmed by a medical practitioner/physiotherapist /trainer	✔	✔	X	X	✔	X	✔	X
No neurological involvement	X	X	✔	X	X	X	X	✔
No previous knee surgery	✔	✔	✔	✔	✔	X	✔	✔
No internal derangement or other sources of lateral knee pain present	✔	✔	✔	✔	✔	✔	✔	✔
No previous spine or lower limb injury	✔	✔	X	✔	✔	✔	✔	X
Total number of inclusion/exclusion criteria present	**12**	**12**	**9**	**7**	**12**	**7**	**12**	**7**

2.3.4 Biomechanical results

The biomechanical results that could not be pooled are summarised in Table 5. The table shows that there is conflicting evidence on the significance of biomechanical changes in the AKP population following taping. There is a large range of different EMG outcomes that have been investigated.

Table 5: Biomechanical results of individual studies

Outcome	Study	Activity	Stastistically significant or not (P-values where available)
VMO/ VL onset timing difference	Cowan et al., 2002	concentric phase stair descent	Yes, (P=0.003)
	Cowan et al., 2002	eccentric phase stair descent	Yes, (P<0.005)
% of max EMG activity VMO	Keet et al., 2007	step up	Yes, (P<0.05)
	Keet et al., 2007	step down	Yes, (P<0.05)
VMO amplitude	Mostamand et al., 2011	Single leg squat	No, (P>0.05)
VL amplitude	Mostamand et al., 2011	Single leg squat	No, (P>0.05)
VMO/ VL onset timing difference	Mostamand et al., 2011	Single leg squat	Yes, (P<0.05)
% change in EMG activity VMO	Cowan et al., 2006	stance phase stair ascent and descent	No, (P=0.232)
% change in EMG activity VL	Cowan et al., 2006	stance phase stair ascent and descent	No, (P=0.171)
Change in PFJRF (N) with taping	Mostamand et al., 2010	Single leg squat	Yes, (P<0.05)
Average peak knee flexion (degrees)	Aminaka et al., 2008	Single leg squat	No, (P=0.732)
Average knee flexion across all conditions (degrees)	Powers et al., 1997	Stair ascent and descent Ramp ascent and descent Gait	Yes, (P<0.05)

2.3.4.1. Kinematics

Two studies investigated knee flexion angles (Aminaka & Gribble, 2008; Powers et al., 1997), however pooling of data was not possible as the studies measured different outcomes. Aminaka & Gribble (2008) measured the average peak knee flexion angle during a unilateral mini-squat whereas Powers et al. 1997, were interested in the knee flexion angle during loading response averaged across all testing conditions. Powers et al., 1997, yielded statistically significant results showing an increase in knee flexion with taping. Conversely, Aminaka & Gribble (2008) yielded no statistically significant results for changes in knee flexion angles.

2.3.4.2 Kinetics

Pooling of data was possible for one kinetic outcome. Figure 4 illustrates the average knee extensor moments during loading response in PFPS subjects with or without tape. There was significant statistical heterogeneity amongst the studies (P=0.02). This indicates that there was substantial variation in the experimental procedures or the studies, thus making it difficult to combine and compare them. One of the studies yielded statistically significant results however the overall effect was not statistically significant (MD, -0.09; 95% CI: -0.19, 0.01).

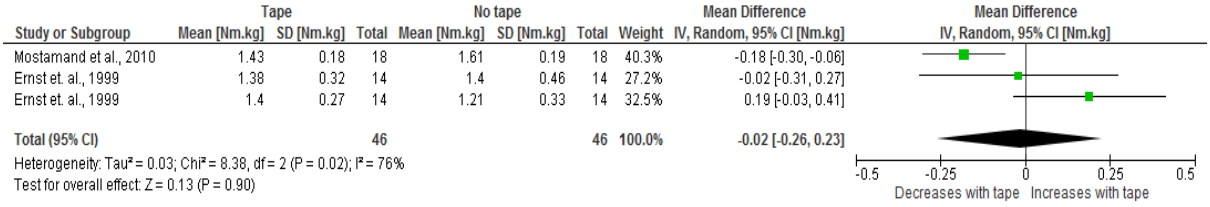


Figure 4: Meta-analysis of average knee extensor moments during loading response in PFPS subjects

Other kinetic outcomes included the mean change in patellofemoral joint reaction force (PFJRF) and average coronal and tranverse plane moments during stance phase of stair descent (Mostamand et al., 2010). PFJ contact force was significantly reduced during a single leg squat when tape was applied to the painful knee (P=0.03). The knee extensor moments demonstrated no change with the application of tape (see Figure 4).

2.4.4.3 Muscle Activation (EMG)

Pooling of data was possible for two EMG outcomes. Figure 5 illustrates the average VMO/VL ratio during the functional weight bearing activity in PFPS subjects with or without tape. There was no statistical heterogeneity amongst the studies. None of the individual studies yielded statistically significant results and therefore the overall effect was not statistically significant (MD, -0.10; 95% CI: -0.25, 0.06).

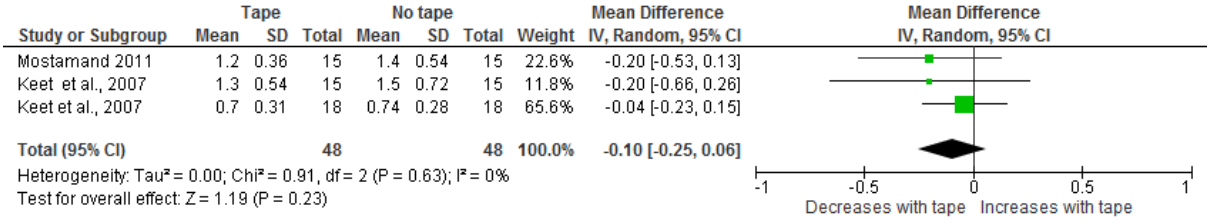


Figure 5: Meta-analysis of average VMO/VL ratio during weight bearing activity in PFPS subjects

The meta-analysis for VMO-VL onset timing difference (Figure 6) demonstrates statistically significant results in one study (Cowan et al., 2002) during both the concentric and eccentric phase of stair descent. However, the overall effect was insignificant (MD, 24.48; 95% CI: -5.99, 54.94).

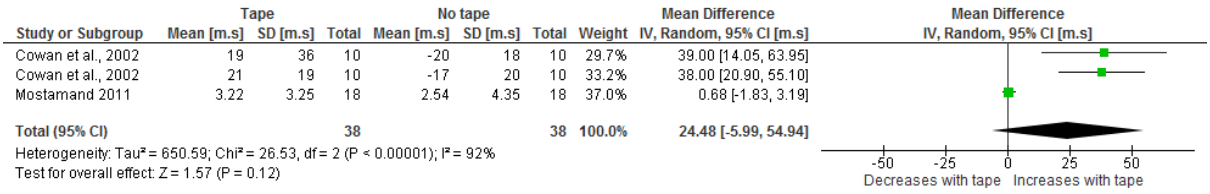


Figure 6: Meta-analysis of average VMO-VL onset timing (m.s)

Other outcomes included percentage of maximum EMG activity of VMO, average VMO amplitude, average VL amplitude, and percentage of change in EMG activity for VMO and VL (Cowan et al., 2002; Keet et al., 2007; Mostamand et al,. 2011; Cowan et al,. 2006). The percentage of maximum EMG activity of VMO was significantly decreased with tape for both a stepping up task and stepping down task

(P<0.05). None of the other outcomes were significantly altered with the application of tape (see Table 5).

2.3.5 Pain outcomes in relation to the biomechanical outcomes

Table 6 shows the pain outcomes for the included studies. Three studies did not describe pain before and after taping. Of the 5 studies that included pain, 4 (Aminaka & Gribble, 2008; Cowan, Hodges, Crossley, & Bennell, 2006; Cowan, Bennell, & Hodges, 2002; Powers et al., 1997) showed an immediate decrease in pain with taping and one study found no difference (Keet et. al., 2007). Three of the studies (Cowan et al., 2006; Cowan et al., 2002; Keet, Gray, Harley, & Lambert, 2007) that included pain had a placebo group and all three found no difference in pain between no taping and placebo taping. Of the included studies, only two studies (Powers et al., 1997 & Cowan et al., 2002) reported less pain and improved biomechanics, specially sagittal plane knee kinematics during gait (Powers et al., 1997) and improved VMO-VL onset timing during the eccentric phase of stair descent (Cowan et al., 2002).

Table 6: Summary of studies which measured pain as an outcome included studies

	Statistically significant reduction in pain with McConnell taping compared to no tape	**Biomechanical change post taping?**	**Description of biomechanical change**
Cowan, Sallie et al., 2002.	Yes, but pain values during step descent following taping intervention were not reported	Yes	There was an improved onset timing of vastii with taping. VMO activation prior to VL with taping
Aminaka, Naoko; Gribble, Phillip, 2008.	Yes, the average pain decreased from 1.45 to 1.07 (P=0.005)	No differences in maximum hip and knee flexion angles	
Keet, Janet et al., 2007.	No change in pain before and after taping. Pain values before and after taping not reported	Yes	There was a significant decrease in the percentage of maximum VMO activity during the step up and step down tests.
Cowan, S M et al., 2006.	Yes, but pain values during step descent following taping intervention were not reported	No change in amplitude of VMO or VL activation or change in VMO/VL ratio	
Powers, C M et al 1997.	Yes, the average pain decreased from 7.7 to 1.7 with tape before activity	Yes	There was a significant increase in loading response knee flexion during gait, stair ascent and descent and ramp ascent and descent.

2.4. DISCUSSION

2.4.1 Summary of main results

This is the first review aimed at assessing the evidence for the biomechanical effects of McConnell taping on the TFJ and PFJ in individuals with AKP. Eight small trials, including a total of 220 participants of which 130 had a diagnosis of AKP were included. Generally, the findings of this review indicate that McConnell taping does not alter knee kinematics and kinetics or muscle activation patterns of the knee muscles.

2.4.2 Kinematics

This review found no significant changes in knee kinematics as a result of McConnell taping. A study by Crossley et al. (2000) concluded that patellar taping might result in increased knee flexion angles during loading. One study (Powers et al., 1997) supported this finding; however the effects were small and it is still difficult to establish the causative mechanisms of this phenomenon. Conversely, Aminaka & Gribble (2008) found no differences in peak knee flexion angles between taped and untaped conditions. Powers et al. (1997), proposed that the loaded flexion angle increased as following an immediate decrease in pain with the application of tape. The decreased pain allowed the subjects to increase their knee flexion during weight-bearing activities. The results of this study should be interpreted with caution, as the study did not report on all outcomes and was missing measures of variability for the kinematic outcome data.

Selfe et al. (2011) investigated the total range of movement of the TFJ with and without taping. The study revealed no significant changes in the sagittal or

transverse plane. There was however, a significant decrease in the coronal plane ROM with taping, which could imply increase stability following taping.

Due to conflicting evidence, it is unclear whether McConnell taping has an effect on any kinematic outcomes.

2.4.3 Kinetics

It is proposed that patellar taping might increase knee extensor moments by improving quadriceps torques (Conway, 1992; Handfield & Kramer, 2000; Salsich et al., 2002). The evidence in our review does not demonstrate a significant effect on knee extensor moments to provide support for this theory. Pooled average knee extensor moment data (Figure 4) from two trials showed no significant benefit from taping. In addition, the meta-analysis (Figure 5) shows a large confidence interval for knee extensor moments, indicating an imprecise finding. This is clinically important as taping is believed to improve the efficacy of knee extensor exercises (McConnell, 1986). If taping does not improve the knee extensor moments it is unlikely that it will be useful in assisting quadriceps strengthening as McConnell (1986) originally proposed. Therefore clinicians should be cautious in prescribing these exercises in the presence of acute AKP.

Independently, one study (Mostamand et al., 2011) demonstrated a decreased patellafemoral joint contact force in the AKP group following taping. The authors estimated the PFJ contact stress through a process of biomechanical modelling using the net knee extensor moment to estimate the quadriceps force. The PFJ reaction force or contact force was then calculated as a product of the quadriceps force. The suggested reason for the decreased reaction force was an improved patellar position following the taping. The authors proposed that the improved

position would improve the efficiency of the quadriceps moment arm thereby decreasing the contact stress. More studies are needed to support these findings.

2.4.4 EMG

Pooled average VMO/VL ratio data from three trials showed no significant change with taping. In addition, the meta-analysis of VMO-VL onset timing data from three trials also demonstrated no significant benefit from taping. Separately, one trial (Keet et al., 2007) demonstrated favourable results after taping for the percentage of maximum EMG activity of VMO was significantly decreased with tape for both a stepping up task and stepping down task. This could indicate that the VMO muscle was working more effectively, however the clinical relevance is unclear. There is a lack of standardisation, for EMG outcomes in particular, making it difficult to compare the results.

The findings of the above study (Keet et al., 2007) are in agreement with a literature review by Overington & Goddard (2006), synthesising the literature on the effect of patellar taping in EMG studies. The review found a lack of standardisation in outcome measures. In addition the results for altered muscle activation with taping are very conflicting with some showing altered activation and some showing no effect. This conflicting evidence may reflect the difficulty in measuring these outcomes and forces one to question the reliability of EMG measurements of muscle activation (Crossley et al., 2001).

It is proposed that individuals with AKP present with a VMO/VL imbalance and a delayed onset of VMO relative to VL (Kim & Song, 2012). In 2004, Christou et al. found that AKP subjects had increased VMO activity and decreased VL activity, post-taping. However McConnell taping and placebo effects were similar which

underscores the need to include placebo taping in future research. The results of this review imply that McConnell taping is not sufficient to address VMO/VL imbalances in subjects with AKP.

2.4.5 Pain

Although it was not the primary objective of this study, we included pain outcomes in the results in order to determine if a change in biomechanics correlates to a change in pain. Four studies (Cowan et al., 2002; Cowan et al., 2006; Aminaka et al., 2008; Powers et al., 1997) showed that pain improved with taping, however only two (Cowan et al., 2002 & Powers et al., 1997) found a relationship between pain and biomechanics. This suggests that even if pain improves, biomechanics do not necessary change. This indicates that the mechanisms of McConnell taping are not necessarily biomechanical, as pain might improve as a result of other mechanisms for example proprioceptive or placebo effects. These aspects should be investigated in future research.

2.4.6 Statistical heterogeneity

Overall, the clinical and statistical heterogeneity of studies was considerable, especially in terms of outcome measures and functional activities investigated. All of the studies compared taping and no taping, however four studies (Cowan et al., 2006; Cowan et al., 2002; Ernst, Kawaguchi, & Saliba, 1999; Keet et al., 2007) included a placebo taping as a control condition.

The McConnell taping approach was used in all of the studies, but the specific technique used varied. Four of the studies used the medial glide technique which is the most commonly used technique for Anterior Knee Pain. Four studies adjusted the technique according to the patella orientation, as described by McConnell in

1986. These corrective techniques included medial glide, medial tilt, anterior tilt and rotation. The specific application procedures of the taping interventions such as the force of application, the type of tape used and the amount of layers of tape applied are also difficult to standardise.

All of the measured activities from the included studies were functional weight-bearing activities that commonly aggravate AKP; however the exact functional activities investigated varied amongst studies. The most commonly used activities were variations of the single leg squat (Aminaka & Gribble, 2008; Mostamand, Bader, & Hudson, 2010, 2011) and stepping tasks or stair climbing (Cowan et al., 2006; Cowan et al., 2002; Keet et al., 2007; Powers et al., 1997), but other activities included vertical jump, lateral step up, ramp ascent and descent and gait. This makes it difficult to compare the studies as the biomechanical requirements of the tasks are different.

One of the biggest challenges in the research of AKP is the variation and lack of consensus of definitions and diagnostic criteria of the subjects. In this review the table of diagnostic criteria as shown in Table 4, shows that there were similarities in how AKP was diagnosed such as the functional activities used to reproduce symptoms and the exclusion of internal derangement. However, common areas of discrepancy are age and the exclusion of neurological involvement. These areas of inconsistency should be addressed in future research.

2.4.7 Measurement of PFJ biomechanics

Only one study (Mostamand et al., 2011) focussed on the biomechanics of PFJ. One reason for this might be that it is difficult to assess the biomechanics of this joint with 3-Dimensional motion analysis and without the use of radiology as it requires 3D

modelling techniques. However, the measurement of PFJ biomechanics before and after taping during functional weight-bearing tasks is a definite shortcoming in the literature. According to previous literature using radiographic methods including x-rays, CT scans and MRI scans the consensus is that taping did not change the alignment and position of the patella (Bockrath, Wooden, Teddy, Chistopher, & Farr, 1993.; Gigante, Pasquinelli, Paladini, Ulisse, & Greco, 2001; Pfeiffer, 2004). One study demonstrated a significant effect for inferior shift (Derasari, Brindle, Alter, Sheehan, & Dynamic, 2010). Pfeiffer et al. 2004, concurred, stating that the beneficial effects of taping were related to factors other than patellofemoral alignment and these other factors remain unknown.

2.4.8 Quality of the evidence

The review protocol was followed and no changes were made. Full text articles that were not available through the University of Stellenbosch database were acquired through inter-library loans. An effort was made to contact authors for missing data, and all of the authors responded. The results of the review were then adapted to include the missing data that met the inclusion criteria.

Two reviewers conducted the searches, reviewed full texts for inclusion or exclusion and did the methodological appraisal independently. There were generally few discrepancies and discrepancies that did occur were discussed. We can therefore conclude that the risk of bias in the process of this review was low.

As shown in the risk of bias summary (Figure 4), all of the included studies had a low risk of selection and attribution bias.

For all of the included studies, the order of the testing conditions was randomised. However, only half of the studies (Cowan et al, 2006; Mostamand et al., 2010; Mostamand et al., 2011; Ernst et al., 1999) described how the randomisation was done. Therefore, we cannot determine if the procedures where truly random and some selection bias might have occurred.

The risk of bias for the included studies was low for the majority of the outcomes. Future studies should include placebo taping and blind the allocation of the participants to a control or placebo group to reduce the risk of selection bias.

2.4.9 Limitations of the review

Only English papers were included in this review. This might have introduced language bias. Our review excluded studies using radiological methods. As a result the evidence on PFJ biomechanics was limited. Our review cannot establish the mechanisms of biomechanical changes in the instances where they were significant results. These limitations should be addressed in future research.

2.4.10 Agreements or disagreements with other studies or review

The evidence is insufficient to draw conclusions on the biomechanical effects of taping. The current evidence does not validate the use of McConnell taping as there were no other clinically or statistically significant findings. This deduction is in agreement with Callagan and Selfe's 2012 review and although the outcomes that they reviewed were different, the same overall conclusion that there is insufficient evidence to support the efficacy of taping was reported. However, both reviews investigated immediate effects only. As this review revealed that there is little evidence of the effect of taping on knee biomechanics during appropriate functional tasks that are commonly associated with AKP.

CHAPTER 3: CONCLUSION

3.1 Clinical Implications

McConnell taping is a frequently used intervention for AKP, as it is simple and inexpensive. However, McConnell taping is not supported by sufficient evidence to justify its routine use. Conclusive recommendations can thus not be formulated for practitioners and educators until there is more evidence about the effect and underlying mechanisms. Educators should exercise caution when recommending McConnell taping as a treatment strategy for Anterior Knee Pain. Clinicians should be encouraged to assess the success of the technique individually with each patient that it is used on. It should be used as part of a multimodal treatment plan and not as a treatment on its own, as the current literature does not justify its use.

Until the mechanisms and effects of individual treatment strategies such as taping are better understood individualised multimodal treatment should be used for individuals with AKP based on the biomechanical and anatomical factors that they present with.

3.2 Limitations of this review

Research needs to focus on establishing the actual causative mechanisms of Anterior Knee Pain. Level I evidence that is aimed at measuring PFJ biomechanics during dynamic activities should be conducted.

The quality of the research as well as the lack of literature on long term outcomes is limiting our knowledge of the disorder itself and the efficacy of interventions. Due to the chronicity of the disorder, long term follow up of research participants is essential. Therefore prospective studies should be considered. In addition, future

research should use single subject designs to control for inter-subject variability as the condition is multifactorial and the presentation varies considerably amongst individuals (Hryvniak, Magrum, & Wilder, 2014).

There are many factors relating to the reliability and procedures of motion analysis and EMG data. These factors have not been addressed in this review and could influence outcomes and possibly account for some of the conflicting results.

In terms of kinematics, the 3D motion analysis equipment that is currently used does not measure movement of the patellofemoral joint. From the kinetics and EMG data one can estimate what is happening at the joint, but the accuracy of this is difficult to determine. Radiographic procedures are most commonly used to measure movement of the patella during active, passive or resisted movement. However, kinematics during a dynamic, functional activity may differ. As technology improves and these measurements become easier to quantify, it will be worthwhile to see if the results differ.

3.3 Recommendations for future research

There is currently little evidence for the effect of McConnell taping on the PFJ during functional dynamic activities. As these are the activities that AKP commonly find painful and challenging, future research should aim to investigate these effects. In order to produce high quality evidence for the effect of the McConnell taping intervention, it is necessary for future research to focus on patellar taping compared to placebo taping.

Good quality evidence such as well-designed RCT's is limited and the researchers were unable to find any N of 1 designs. It is challenging to evaluate an intervention

for a condition that itself is not well understood. It is important to have knowledge of the risk factors and causative mechanisms in order to know which components to address. Current research is attempting to clarify definitions and shed some light on the aetiology of this complex condition. This will enable researchers to focus on specific targeted intervention to address the biomechanical causes.

An intervention that targets biomechanics will not be effective if the underlying cause of the condition is not biomechanical. Other potential mechanisms of action such as proprioceptive mechanisms should be investigated. There is some evidence that sub-classification of subjects with AKP may be of benefit, but further research into this area is required (Hryvniak et al., 2014).

Prospective studies are needed to monitor adherence to treatment for longer than a year. This will enable researchers to better understand the long term effects of current patellar taping and other interventions for AKP.

3.4 Conclusion

The findings of this Thesis demonstrate that there is currently inadequate evidence for the effect of McConnell taping on biomechanics and muscle activation in individuals with Anterior Knee Pain. This necessitates the questioning of the routine use of patellar taping in clinical practice. Given the multifactorial causes of AKP, McConnell's simplistic treatment approach might not be valid. However, one cannot rule out other potential mechanisms of effect such as proprioceptive mechanisms, which should be addressed in future research. Moreover, prospective Level I evidence is needed to investigate the efficacy of McConnell taping. Further research of the patellofemoral joint during functional weight-bearing activities is required.

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Internet sources:

Cochrane guidelines: http://handbook.cochrane.org/

McMaster university: http://fhs.mcmaster.ca/medicine/residency/halfday_ebm.html

Appendices

Appendix A: Search Strategy

Pubmed

Limits applied to the database:

Type of search: Advanced search

Publication dates: Inception to September 2014

Publication type: Clinical trial, Controlled clinical trial

Randomised controlled trial (RCT)

Language: English

Age groups: All

Search terms:
1. **Taping**
2. **Anterior knee pain [MESH]**
3. **#1 AND #2**
4. **Kinematics OR kinetics OR electromyography**
5. **#1 AND #2 AND #4**
6. **Effect* OR outcome* OR result***
7. **#1 AND #2 AND #6**
8. **#1 AND #2 AND #6 AND (trial*)**

Scopus

Limits applied to the database:

Type of search:	Advanced search
Publication dates:	Inception to September 2014
Language:	English
Content type:	Journal article
Subject area:	Health sciences

Search terms:
1. Taping
2. Anterior knee pain OR patellofemoral pain syndrome
3. Biomechanics
4. #1 AND #2
5. #1 AND #2 AND #3

PEDro

Limits applied to in database:

Type of search:	Simple search
Publication dates:	Inception to September 2014
Publication types:	Clinical trial, Controlled Clinical Trial, RCT
Language:	English

Search terms:
1. **Taping**
2. **Anterior knee pain OR patellofemoral pain syndrome**
3. **#1 and #2**
4. **Kinematics OR kinetics Or electromyography**
5. **#1 AND #2 AND #4**
6. **#5 AND (Effect* or outcome* OR result*)**
7. **#6 and (trial*)**

Science Direct

Limits applied to the database:

Type of search:	Advanced search
Publication dates:	Inception to September 2014
Publication type:	Clinical trial, Controlled Clinical Trial, RCT
Additional filter(s):	English
Content type:	Journal article

Search terms:
1. **Taping**
2. **Anterior Knee Pain OR patellofemoral pain**
3. **#1 AND #2**
4. **Kinematics OR kinetics OR electromyography**
5. **#1 and #2 and #4**

Ebscohost: **Medline, CINAHL, SportDiscus**

Limits applied to the database:

Type of search:	Advanced search
Publication dates:	Inception to September 2014
Publication type:	Clinical trial, Randomised controlled trial
Language:	English

Search terms:
1. Taping
2. Anterior knee pain or patellofemoral pain syndrome
3. #1 AND #2
4. Kinematics OR kinetics OR electromyography
5. #1 AND #2 AND #4
6. #1 AND #2 AND #4 AND (trial*)

Appendix B: Cochrane Collaboration's risk of bias assessment tool

The Cochrane Collaboration's tool for assessing risk of bias

Domain	Description	Review authors' judgement
Sequence generation	Describe the method used to generate the allocation sequence in sufficient detail to allow an assessment of whether it should produce comparable groups.	Was the allocation sequence adequately generated?
Allocation concealment	Describe the method used to conceal the allocation sequence in sufficient detail to determine whether intervention allocations could have been foreseen in advance of, or during, enrolment.	Was allocation adequately concealed?
Blinding of participants, personnel and outcome assessors *Assessments should be made for each main outcome (or class of outcomes)*	Describe all measures used, if any, to blind study participants and personnel from knowledge of which intervention a participant received. Provide any information relating to whether the intended blinding was effective.	Was knowledge of the allocated intervention adequately prevented during the study?
Incomplete outcome data *Assessments should be made for each main outcome (or class of outcomes)*	Describe the completeness of outcome data for each main outcome, including attrition and exclusions from the analysis. State whether attrition and exclusions were reported, the numbers in each intervention group (compared with total randomized participants), reasons for attrition/exclusions where reported, and any re-inclusions in analyses performed by the review authors.	Were incomplete outcome data adequately addressed?
Selective outcome reporting	State how the possibility of selective outcome reporting was examined by the review authors, and what was found.	Are reports of the study free of suggestion of selective outcome reporting?
Other sources of bias	State any important concerns about bias not addressed in the other domains in the tool. If particular questions/entries were pre-specified in the review's protocol, responses should be provided for each question/entry.	Was the study apparently free of other problems that could put it at a high risk of bias?

Possible approach for *summary assessments* outcome (across domains) within and across studies

Risk of bias	Interpretation	Within a study	Across studies
Low risk of bias	Plausible bias unlikely to seriously alter the results.	Low risk of bias for all key domains.	Most information is from studies at low risk of bias.
Unclear risk of bias	Plausible bias that raises some doubt about the results	Unclear risk of bias for one or more key domains.	Most information is from studies at low or unclear risk of bias.
High risk of bias	Plausible bias that seriously weakens confidence in the results.	High risk of bias for one or more key domains.	The proportion of information from studies at high risk of bias is sufficient to affect the interpretation of the results.

Criteria for judging risk of bias in the 'Risk of bias' assessment tool

SEQUENCE GENERATION **Was the allocation sequence adequately generated? [Short form: *Adequate sequence generation*?]**	
Criteria for a judgement of 'YES' (i.e. low risk of bias).	The investigators describe a random component in the sequence generation process such as: ▪ Referring to a random number table; Using a computer random number generator; Coin tossing; Shuffling cards or envelopes; Throwing dice; Drawing of lots; Minimization*. *Minimization may be implemented without a random element, and this is considered to be equivalent to being random.
Criteria for the judgement of 'NO' (i.e. high risk of bias).	The investigators describe a non-random component in the sequence generation process. Usually, the description would involve some systematic, non-random approach, for example: ▪ Sequence generated by odd or even date of birth; ▪ Sequence generated by some rule based on date (or day) of admission; ▪ Sequence generated by some rule based on hospital or clinic record number. Other non-random approaches happen much less frequently than the systematic approaches mentioned above and tend to be obvious. They usually involve judgement or some method of non-random categorization of participants, for example: ▪ Allocation by judgement of the clinician; ▪ Allocation by preference of the participant; ▪ Allocation based on the results of a laboratory test or a series of tests; ▪ Allocation by availability of the intervention.
Criteria for the judgement of 'UNCLEAR' (uncertain risk of bias).	Insufficient information about the sequence generation process to permit judgement of 'Yes' or 'No'.
ALLOCATION CONCEALMENT **Was allocation adequately concealed? [Short form: *Allocation concealment*?]**	
Criteria for a judgement of 'YES' (i.e. low risk of bias).	Participants and investigators enrolling participants could not foresee assignment because one of the following, or an equivalent method, was used to conceal allocation: ▪ Central allocation (including telephone, web-based, and pharmacy-controlled, randomization); ▪ Sequentially numbered drug containers of identical appearance; ▪ Sequentially numbered, opaque, sealed envelopes.
Criteria for the judgement of 'NO' (i.e. high risk of bias).	Participants or investigators enrolling participants could possibly foresee assignments and thus introduce selection bias, such as allocation based on: ▪ Using an open random allocation schedule (e.g. a list of random numbers); ▪ Assignment envelopes were used without appropriate safeguards (e.g. if envelopes were unsealed or non-opaque or not sequentially numbered); ▪ Alternation or rotation; ▪ Date of birth; ▪ Case record number; ▪ Any other explicitly unconcealed procedure.

Criteria for the judgement of 'UNCLEAR' (uncertain risk of bias).	Insufficient information to permit judgement of 'Yes' or 'No'. This is usually the case if the method of concealment is not described or not described in sufficient detail to allow a definite judgement – for example if the use of assignment envelopes is described, but it remains unclear whether envelopes were sequentially numbered, opaque and sealed.
BLINDING OF PARTICIPANTS, PERSONNEL AND OUTCOME ASSESSORS **Was knowledge of the allocated interventions adequately prevented during the study? [Short form: *Blinding*?]**	
Criteria for a judgement of 'YES' (i.e. low risk of bias).	Any one of the following: ▪ No blinding, but the review authors judge that the outcome and the outcome measurement are not likely to be influenced by lack of blinding; ▪ Blinding of participants and key study personnel ensured, and unlikely that the blinding could have been broken; ▪ Either participants or some key study personnel were not blinded, but outcome assessment was blinded and the non-blinding of others unlikely to introduce bias.
Criteria for the judgement of 'NO' (i.e. high risk of bias).	Any one of the following: ▪ No blinding or incomplete blinding, and the outcome or outcome measurement is likely to be influenced by lack of blinding; ▪ Blinding of key study participants and personnel attempted, but likely that the blinding could have been broken; ▪ Either participants or some key study personnel were not blinded, and the non-blinding of others likely to introduce bias.
Criteria for the judgement of 'UNCLEAR' (uncertain risk of bias).	Any one of the following: ▪ Insufficient information to permit judgement of 'Yes' or 'No'; ▪ The study did not address this outcome.
INCOMPLETE OUTCOME DATA **Were incomplete outcome data adequately addressed? [Short form: *Incomplete outcome data addressed*?]**	
Criteria for a judgement of 'YES' (i.e. low risk of bias).	Any one of the following: ▪ No missing outcome data; ▪ Reasons for missing outcome data unlikely to be related to true outcome (for survival data, censoring unlikely to be introducing bias); ▪ Missing outcome data balanced in numbers across intervention groups, with similar reasons for missing data across groups; ▪ For dichotomous outcome data, the proportion of missing outcomes compared with observed event risk not enough to have a clinically relevant impact on the intervention effect estimate; ▪ For continuous outcome data, plausible effect size (difference in means or standardized difference in means) among missing outcomes not enough to have a clinically relevant impact on observed effect size; ▪ Missing data have been imputed using appropriate methods.
Criteria for the judgement of 'NO' (i.e. high risk of bias).	Any one of the following: ▪ Reason for missing outcome data likely to be related to true outcome, with either imbalance in numbers or reasons for missing data across intervention groups; ▪ For dichotomous outcome data, the proportion of missing outcomes compared with observed event risk enough to induce clinically relevant bias in intervention effect estimate; ▪ For continuous outcome data, plausible effect size (difference in means or standardized difference in means) among missing outcomes enough to induce clinically relevant bias in observed effect size; ▪ 'As-treated' analysis done with substantial departure of the intervention received from that assigned at randomization; ▪ Potentially inappropriate application of simple imputation.

Criteria for the judgement of 'UNCLEAR' (uncertain risk of bias).	Any one of the following: ▪ Insufficient reporting of attrition/exclusions to permit judgement of 'Yes' or 'No' (e.g. number randomized not stated, no reasons for missing data provided); ▪ The study did not address this outcome.
SELECTIVE OUTCOME REPORTING **Are reports of the study free of suggestion of selective outcome reporting? [Short form: *Free of selective reporting*?]**	
Criteria for a judgement of 'YES' (i.e. low risk of bias).	Any of the following: ▪ The study protocol is available and all of the study's pre-specified (primary and secondary) outcomes that are of interest in the review have been reported in the pre-specified way; ▪ The study protocol is not available but it is clear that the published reports include all expected outcomes, including those that were pre-specified (convincing text of this nature may be uncommon).
Criteria for the judgement of 'NO' (i.e. high risk of bias).	Any one of the following: ▪ Not all of the study's pre-specified primary outcomes have been reported; ▪ One or more primary outcomes is reported using measurements, analysis methods or subsets of the data (e.g. subscales) that were not pre-specified; ▪ One or more reported primary outcomes were not pre-specified (unless clear justification for their reporting is provided, such as an unexpected adverse effect); ▪ One or more outcomes of interest in the review are reported incompletely so that they cannot be entered in a meta-analysis; ▪ The study report fails to include results for a key outcome that would be expected to have been reported for such a study.
Criteria for the judgement of 'UNCLEAR' (uncertain risk of bias).	Insufficient information to permit judgement of 'Yes' or 'No'. It is likely that the majority of studies will fall into this category.
OTHER POTENTIAL THREATS TO VALIDITY **Was the study apparently free of other problems that could put it at a risk of bias? [Short form: *Free of other bias*?]**	
Criteria for a judgement of 'YES' (i.e. low risk of bias).	The study appears to be free of other sources of bias.
Criteria for the judgement of 'NO' (i.e. high risk of bias).	There is at least one important risk of bias. For example, the study: ▪ Had a potential source of bias related to the specific study design used; or ▪ Stopped early due to some data-dependent process (including a formal-stopping rule); or ▪ Had extreme baseline imbalance; or ▪ Has been claimed to have been fraudulent; or ▪ Had some other problem.
Criteria for the judgement of 'UNCLEAR' (uncertain risk of bias).	There may be a risk of bias, but there is either: ▪ Insufficient information to assess whether an important risk of bias exists; or ▪ Insufficient rationale or evidence that an identified problem will introduce bias.

Appendix C: Data management form

Database	Initial hits	Duplicates	Excluded on title	Exclusion on abstract	Exclusion on full text	Included	References
Pubmed	19	0	5	7	4	4	Mostamand 2010 Cowan 2002 Cowan 2006 Mostamand 2011
Ebscohost	76	40	22	11	2	1	Powers 1997
Scopus	24	3	9	5	6	1	Aminaka 2008
Science Direct	21	1	5	10	4	1	Keet 2007
Pedro	42	6	17	16	2	1	Ernst 1999
	182	50	58	48	18	8	

Appendix D: Data extraction form

Author	year	Title	Sample description	sample (n)	Method	Design	Results, means and SD	Results 95% CI	Results (P)
Mostamand, Javid Bader, Dan L Hudson, Zöe	2011	The effect of patellar taping on EMG activity of vasti muscles during squatting in individuals with patellofemoral pain syndrome.	18 PFPS, 18 matched controls 11 men and 7 women per group Mean age was 28	36	Participants with patellofemoral pain syndrome were then asked to perform a shallow single leg squat, of approximately 45 degrees of knee flexion on the affected leg and hold it for 10 s to record any resulting pain on the standard 100 mm visual analogue scale. They were then instructed to stand on one leg and to keep the contralateral leg off the floor. Participants executed a single leg squat from a neutral position to a depth of 45 degrees of knee flexion , while maintaining heel contact with the floor. Thus a maximum period	Randomised cross-over 2 groups	Means and SD VMO-VL onset (m/s) PFPS before 2.54 (4.35) PFPS during -3.22 (4.45) PFPS after -6.00 (3.40) Controls without tape -2.03 (6.04)	VMO-VL onset (m/s) PFPS before 0.376796 to 4.703204 PFPS during 5.43293 to 1.00707 PFPS after 7.69078 to 4.30922 Controls without tape -5.03362 to 0.973621	Vastus medialis obliquus- vastus lateralis onset prior to taping were decreased significantly following an immediate application of tape and after a prolonged period of taping ($P < 0.05$). Differences between the ranked values of vastus medialis obliquus/vastus lateralis amplitude of the affected and unaffected knees of participants with patellofemoral

					of 12 s was assigned to three repetitions, including the first 3 s of the test period for concordance of participants with the activity. EMG data recording and collection was halted when the participants completed the three single leg squats. On completion of this procedure, an identical test procedure was repeated on the contralateral leg.				pain syndrome and controls during different conditions of taping (P > 0.05)
Cowan, Sallie M Bennell, Kim L Hodges, Paul W	2002	Therapeutic patellar taping changes the timing of vasti muscle activation in people with patellofemoral pain syndrome.	Ten participants (three male, seven female) diagnosed with PFPS on the basis of clinical examination by an experienced musculoskeletal physiotherapist, and 12 asymptomatic controls (four male, eight female) were	22	With each intervention (therapeutic tape, placebo tape, and no tape), participants performed the stair stepping task. Participants stood 1.8 m from the lower step and were instructed to ascend and descend the stairs at a rate of 96 steps per minute as	Randomised cross-over 1 group	Pain group with taping: onset timing difference Concentric) = 20 , SEM= 4 Eccentric) = 22, SEM= 10 Control group Concentric) Mean= 13.5, SEM=4 Eccentric) Mean=-1.5, SEM= 7	Not given	The taping procedures produced different effects in the PFPS and control group (p < 0.0001). In the PFPS group there were no differences between the no

			recruited for the study.		paced by an external metronome to ensure that repetitions were consistent.20 Participants completed approximately five practice trials to ensure that they were able to step in time with the metronome and contact the middle step with the test leg. Recordings of EMG activity of VMO and VL were made during the stance phase on the middle stair during ascent and descent for five consecutive trials during each intervention A 5-minute break was enforced between each taping condition to ensure that skin sensation returned to normal levels Taping was applied in a standard sequence until the participant's pain was reduced by at least				tape and placebo tape conditions (p = 0.124 concentric and p = 0.187 eccentric). There were, however, differences between the no tape and therapeutic tape conditions (p = 0.003 concentric and p < 0.005 eccentric). There was also a difference between the placebo tape and therapeutic tape conditions in the concentric phase of the stair stepping task (p < 0.002), but the difference was not significant in the eccentric

					50% during an aggravating activity assessed on a 10- cm VAS. If necessary, to ensure a 50% reduction in pain, the tape was applied in knee flexion.				phase (p = 0.025). In the PFPS group, when the patella was taped, the EMG onset of VMO occurred before VL in the concentric phase of the stair stepping task (p < 0.001)
Aminaka, Naoko Gribble, Phillip a	2008	Patellar taping, patellofemoral pain syndrome, lower extremity kinematics, and dynamic postural control.	20 PFPS(12 females, 8 males) 20 matched controls Mean age 21.27	40	Participants were instructed to reach as far as possible with the reaching leg and touch the designated tapeline lightly with the most distal part of the foot while minimising the transfer of the body weight from the stance leg and keeping the hands on the hips. 6 practice trials were given followed by 5 minutes of rest, then 3 trials were recorded in	Repeated-measures design with 2 within-subjects factors and 1 between-subjects factor.	Control: Means (SE) Tape injured: Knee flexion=48.4 (3.911) Uninjured: Knee flexion= 49.1 (3.81) No Tape Injured: knee flexion=48.85 (3.98) Unjured: kneeflexion=50.24 (3.629) PFPS: Tape injured: (3.231), knee flexion= 45.151 (3.812) Uninjured: knee	Not given	Knee flexion angles at maximum reach distance: P=0.548 tape-by-side by group interaction P=0.732 main effects of tape P=0.906 injured side differences P=0.307 group differences (pain versus control)

					the untapped conditions, followed by 5 minutes of rest and then 3 trials were recorded in the taped conditions. The whole procedure was then repeated with the other leg.		flexion= 42.892 (3.714) No Tape Injured hip flexion= 7.356 (3.353), knee flexion= 43.803 (3.88) Unjured hip flexion= 7.565 (3.108), knee flexion= 43.402 (3.537)		
Keet, Janet H.L. Gray, Janine Harley, Yolande Lambert, Mike I.	2007	The effect of medial patellar taping on pain, strength and neuromuscular recruitment in subjects with and without patellofemoral pain	15 with PFPS, 11 female and 4 male 20 controls, 13 female and 8 male Mean age 29 Recruited from Sport Science institute of South Africa	35	The tape was applied by an experienced physiotherapist. with three randomised interventions for each subject (1) with medial patellar tape; (2) with placebo tape; and (3) with no tape. EMG data from the bellies of vastus medialis oblique and vastus lateralis muscles were collected during isokinetic, isometric and functional testing were recorded. All subjects were familiarised with the	placebo-controlled clinical trial	VMO amplitude (means, 95% CI) PFPS group NO TAPE PLACEBO TAPE step up 77 (62-92) 77(62-93) 64 (53-75) step down 85 (70-101) 81(68-93) 72 (60-85) Control group step up 60 (49-71) 62 (51-72) 47 (40-54) step down 66 (55-76) 65 (55-75) 55 (45-65) VMO/VL ratio (means, 95% CI) PFPS group NO TAPE PLACEBO TAPE step up 1.5 (1.1-2.0)	VMO amplitude PFPS group NO TAPE PLACEBO TAPE step up (62-92), (62-93), (53-75) step down 85 (70-101) 81(68-93) 72 (60-85) Control group step up (49-71), (51-72), (40-54) step down (55-76), (55-	EMG activity of the vastus medialus oblique was 28% greater during the step-up test and 29% greater during the step-down test (P<0.05) in the patellofemoral pain group compared with the healthy cohort with no tape. Furthermore, vastus medialus oblique/vastus

					equipment and testing procedure prior to the start of data collection. Subjects were asked to perform 10 submaximal concentric and eccentric actions of the quadriceps, gradually progressing from 50 to 90%of their maximum, as part of the warm-up. Thereafter, three maximal voluntary concentric and eccentric actions of the quadriceps were performed. This test was followed by a warm-up of five submaximal isometric actions of the quadriceps with a 5-second hold and 5-second rest period between each action. This was followed by three maximal voluntary isometric quadriceps contractions of 5 seconds duration. For all these tests, the action		1.5 (1.1-1.9) 1.3 (1.0-1.6) step down 1.4 (1.1-1.7) 1.4 (1.1-1.6) 1.2 (1.0-1.5) Control group step up 1.4 (1.1-1.6) 1.5 (1.2-1.7) 1.1 (1.0-1.3) step down 1.3 (1.1-1.5) 1.2 (1.1-1.4) 1.1 (0.9-1.2)	75) , (45-65) VMO/VL ratio (means, 95% CI) PFPS group NO TAPE PLACEBO TAPE step up (1.1-2.0) , (1.1-1.9) , (1.0-1.6) step down (1.1-1.7), (1.1-1.6), (1.0-1.5) Control group step up (1.1-1.6), (1.2-1.7) , (1.0-1.3) step down (1.1-1.5), (1.1-1.4), (0.9-1.2)	lateralis ratios were significantly ($p<0.05$) lower during the step tests with tape compared with their respective no-tape measurements, in both groups. No significant differences were evident between groups with regard to EMG activity of the vastus lateralis or the vastus medialus oblique/vastus lateralis ratio with and without tape.

					producing the greatest peak force was recorded for analysis. EMG data were recorded simultaneously. The functional test consisted of a step-up followed immediately by a step-down with the same leg, over a 20-cm step, performed in time to a recorded voice counting 3 seconds for the step-up and 3 seconds for the step-down, and repeated three times.				
Mostamand, Javid Bader, Dan L Hudson, Zöe	2010	The effect of patellar taping on joint reaction forces during squatting in subjects with Patellofemoral Pain Syndrome (PFPS).	18 PFPS, 18 controls PFPS group: 11 men, 7 women in each group Mean 27.9 (6.3) Aged less than 40 years (both genders) Controls: No history of knee pain Age 26.4 (4.9)	36	Patellofemoral Joint Reaction Force (PFJRF) were assessed by a motion-analysis system and one force plate. This procedure was performed on the affected knee of subjects with PFPS, before, during and finally after patellar taping during unilateral	Randomised cross-over 2 groups	The mean value of PFJRF of the affected knee in subjects with PFPS before applying the tape (2025 N, SD 347 N) was greater than the mean PFJRF for the corresponding values of the unaffected knees (1895 N, SD 286 N) The mean value of	PFJRF of the affected knee in subjects with PFPS before applying the tape and unaffected knees (-345.4-85.4) No significant difference	PFJRF of the affected knee in subjects with PFPS before applying the tape and corresponding values of the unaffected knees. ($P<0.05$). PFJRF in the

					squatting. A similar procedure was also performed on the unaffected knees of both groups.		PFJRF in the before-taped condition was also greater than the taped condition (1796 N, SD 297 N) and after applying the tape (1720 N, SD 303 N) in the affected knees. No significant difference between the mean values of PFJRF in the before-taped condition and no-tape condition, in both knees of healthy control subjects (1922 N, SD 398 N)	between the mean values of PFJRF in the before-taped condition and no-tape condition, in both knees of healthy control subjects (1922 N, 1724.079-2119.921)	before-taped condition was also greater than the taped condition and after applying the tape in the affected knees. PFJRF in the before-taped condition and no-tape condition, in both knees of healthy control subjects . (P>0.05)
Ernst, G P Kawaguchi, J Saliba, E	1999	Effect of patellar taping on knee kinetics of patients with patellofemoral pain syndrome.	14 women with PFPS Mean age 24.4 (5.8) Unilateral PFPS Duration varied from 6 weeks to 10 years	14 PFPS	Each subject performed 3 vertical jumps and 3 lateral step ups for each condition (McConnell tape, placebo tape, no tape, and the uninvolved lower extremity). The order of the lateral step up and vertical jump was alternated for each condition. Subjects were allowed 3	Single group, experimental repeated measures	Means and SDs KEM for lateral step up: Tape= 1.40 (0.27), placebo= 1.28 (0.28), No tape= 1.21 (0.33) KEM for vertical jump: Tape= 1.73 (0.36), placebo= 1.38 (0.32), no tape= 1.40 (0.46)	KEM for lateral step up: Tape= (1.244-1.556), placebo= (1.118-1.442), No tape= (1.0195-1.565) KEM for vertical jump: Tape= (1.522-1.938),	The first ANOVA evaluating the effect of patellar taping on knee extensor moment revealed a main effect for McConnel Taping (P = .003). Turkey's HSD post hoc

					to 6 practice trials of each activity prior to data collection			placebo= (1.195-1.565), no tape= (1.135-1.666)	analysis demonstrated that the McConnell tape condition resulted in a greater knee extensor moment then no type and placebo tape
Cowan, S M Hodges, P W Crossley, K M Bennell, K L	2006	Patellar taping does not change the amplitude of electromyographic activity of the vasti in a stair stepping task.	PFP were: age 23.0 (8.0) years, control participants were: 19.5 (1.4) years Gender not mentioned Duration at least one month for pain group	10 PFPS 12 asymptomatic controls	Ten participants with PFP and 12 asymptomatic controls were recruited to the study. . Participants completed a stair stepping task. Three experimental conditions were assessed: no tape, therapeutic medially directed tape, and placebo vertically directed tape.	Randomised cross-over, 2 group	% change in EMG activity Means and SD VMO: PFPS increased activation= 34 (22), decreased activation= 23 (15) Controls increased activation= 8 (25), decreased activation= 23 (13) VL: PFPS increased activation= 22 (31), decreased activation= 6 (7) Controls increased activation= 4 (3),	% change in EMG activity VMO: PFPS increased activation= 18.26-49.74, decreased activation= 12.27-33.73 Controls increased activation= -7.88-23.88, decreased activation= 14.74-31.26 VL: PFPS	EMG amplitudes: No differences between the control and PFP group (p = 0.215), no differences between muscles (p = 0.136) or taping conditions (p = 0.784), and there were no significant interactions between muscle and group (p =

							decreased activation= 17 (10)	increased activation= -0.18-44.18, decreased activation= 0.99-11.01 Controls increased activation= 2.09-5.91, decreased activation= 10.65-23.35	0.472), tape and group (p = 0.115), muscle and tape (p = 0.232), or muscle, tape, and group (p = 0.227). EMG activity ratio (VMO/VL) in the three taping conditions for the control and PFP groups: no differences between taping conditions in either the control (p = 0.171) or the PFP group (p = 0.256).
Powers, C M Landel, R Sosnick, T Kirby, J Mengel, K Cheney, A	1997	The effects of patellar taping on stride characteristics and joint motion in subjects with patellofemoral pain.	15 females 14-41 years Age: 26.5 (7.2) Unilateral knee pain	15 PFPS	Stride characteristics and sagittal plane joint motion were recorded simultaneously during taped and untaped trials of free walking, fast walking, and ascending and descending a ramp	Randomized cross-over, 1 group	Stride length taped during stair ascent 1.37, untapped 1.28 Loading response knee flexion with taping. 26.1, untapped 22.7	Not given	No significant differences in gait velocity or cadence between taped and untapped (P>0.05) Significant stride

					and stairs. A total of four trials for each condition was performed, two with the painful knee taped and two with- out tape. The order of the taped and untaped trials as well as the order of the conditions was randomised for each subject.				length improvement following taping during ramp ascent (P<0.05) Significant increase in loading response knee flexion with taping. (P<0.05)

Appendix E: Details of excluded studies

AUTHOR	YEAR	REASON FOR EXCLUSION
Anderson &Herrington	2003	Activity
Bockrath et al.	1993	Study design
Cerny	1995	Diagnostic criteria
Gilleard et al.	1998	Diagnostic criteria

Handfield & Kramer	2000	Diagnostic criteria
Harrison & Sheppard	1999	Outcomes
Herrington & Payton	1997	Study design
Kowall et al.	1996	Intervention
Lan et al.	2010	Study design
Lee & Cho	2013	Diagnostic criteria
Mason et al.	2011	Outcomes
Ng & Wong	2009	Diagnostic criteria
Ng & Cheng	2002	Diagnostic criteria
Osorio et al.	2013	Outcomes
Paoloni et al.	2012	Study design
Pfeiffer	2004	Activity
Salsich et al.	2002	Study design

Selfe et al.	2011	Not McConnell taping

Appendix F: Journal guidelines for Journal of Sports Biomechanics

Instructions for authors

SCHOLARONE MANUSCRIPTS™

This journal uses ScholarOne Manuscripts (previously Manuscript Central) to peer review manuscript submissions. Please read the guide for ScholarOne authors before making a submission. Complete guidelines for preparing and submitting your manuscript to this journal are provided below.

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Contents List

Manuscript preparation

1. General guidelines

↑Back to top.

For authors whose native language is not English, it is strongly recommended they use a professional editing service to improve the quality of writing and screen out grammatical errors prior to manuscript submission. Manuscripts can be rejected on the basis of quality of writing. During the course of manuscript review, the Editor-in-Chief or the Associate Editor may require authors to provide proof that such an editing service was used when it was recommended through the review process. Use of such an editing service, however, does not guarantee manuscript acceptance and the quality will be judged by the Editor-in-Chief and the Associate Editor.

Authors should endeavour to write in a style that is 'reader friendly' and, in particular, 'coach friendly'. Achieving this while maintaining scientific rigour is obviously a major challenge for authors, reviewers and the editorial team. The avoidance of non-standard abbreviations and mnemonics greatly enhances a paper's readability, as does writing in plain idiomatic English. Keeping the paragraphs in reasonable lengths with clear key points will also help improving the manuscript's readability.

- Manuscripts are accepted in English. British English spelling and punctuation are preferred. Please use single quotation marks, except where ‘a quotation is “within” a quotation’. Long quotations of words or more should be indented without quotation marks.
- Manuscripts should be double spaced in 12 Font with normal character spacing. Add continuous line numbers to the main document (abstract to appendices) as reviewers will use only the line numbers to specify locations in the manuscript. Do not restart line numbers on each page. Allow at least 25 mm borders at top, bottom, left and right of each page, laid out as if to be printed on A4 or Letter-size paper.
- Please be very careful to conform to the format for figures, tables, references, and overall style established for ***Sports Biomechanics*** . In the case of citations and references, please use the style and punctuation conventions given below.
- Manuscripts should be compiled in the following order: title page (including Acknowledgements as well as Funding and grant-awarding bodies); abstract; keywords; main text; acknowledgements; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figure caption(s) (as a list).
- Abstracts of no more than 200 words are required for all manuscripts submitted.
- Each manuscript should have 3 to 5 keywords that are not included in the title.
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- Section headings should be concise.
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2. Style guidelines

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- Description of the Journal's article style.
- Description of the Journal's reference style.
- Guide to using mathematical scripts and equations.

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Title:
The title should reflect the practical importance of the research as well as indicate its scientific basis.

Abstract:

The abstract should be not more than 200 words. Include the word count at the end of the abstract. The abstract should summarise the main findings and should conclude with clear statements off the research questions of the study. Refrain from including generic or explanatory statements in the abstract. Construct the abstract in a single paragraph with no subheading.

Introduction:

The introduction should clearly elaborate the potential benefits of the research and its findings for sport practitioners. The purposes (aims and objectives) should be stated so as to capture both the contribution to knowledge and the practical benefits of the study. All hypotheses should be clearly formulated based on a sound theoretical framework. Plain descriptive studies with no systematic research focus or underlying theoretical framework won't be accepted. Authors should elaborate on explaining the mechanisms, not on simply describing the phenomena. The research questions and hypotheses should be justified fully within the introduction and the rest of the manuscript must be tightly organized around the research questions/hypotheses. The hypothesis must be included at the end of this section.

Methods:

The methods section should document the overall procedures and the participants involved, provide sufficient detail to allow replication of the study, and give relevant technical information to establish clearly the scientific merit of the study. However, authors should seek to make this material comprehensible to a non-specialist reader and provide guidance when technical information is presented. Material that is difficult for a non-specialist reader, such as complex mathematical models, should be included as an appendix and referred to in the methods section.

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The methods may also incorporate the following:

1. Definitions of technical terms.

2. If appropriate, and if not already incorporated into the introduction, a description of the rationale for selecting particular variables for analysis and their relationship to performance or injury should be included.

3. Where appropriate, information to establish the validity and reliability of the methods, and the magnitude of errors, should be provided, except in review papers. A statement that approval for the study was obtained from the appropriate research ethics committee must be included.

Results:

Sport practitioners should not be prevented from grasping the results because of a lack of knowledge of statistical procedures and terminology. However, no claims should be made without citing the relevant statistical results. Avoid using redundant numerical data in the text that are already presented in the tables and/or figures. Avoid using generic and narrative statements. Refer to relevant tables and figures parenthetically whenever possible and refrain from using expressions such as "Figure/Table x shows…." excessively.

Discussion and Implications:

This section should be separate from the results section and should elaborate the implications of the results; it should also make clear the limitations of the study. It should be possible to read this section without recourse to the statistical results or further statistical information and terminology. Practitioners should be able to skip the results section and understand the findings of the study, and their implications for sport performance or injury prevention, from the discussion and implications section alone. Achieving this requires skill from authors to restate findings simply without repeating unnecessarily the information provided in the results section. If appropriate, this section may include coaching practices, training drills and activities that are indicated by, or arise from, the research or review. It is important to keep the discussion within the scope of the study.

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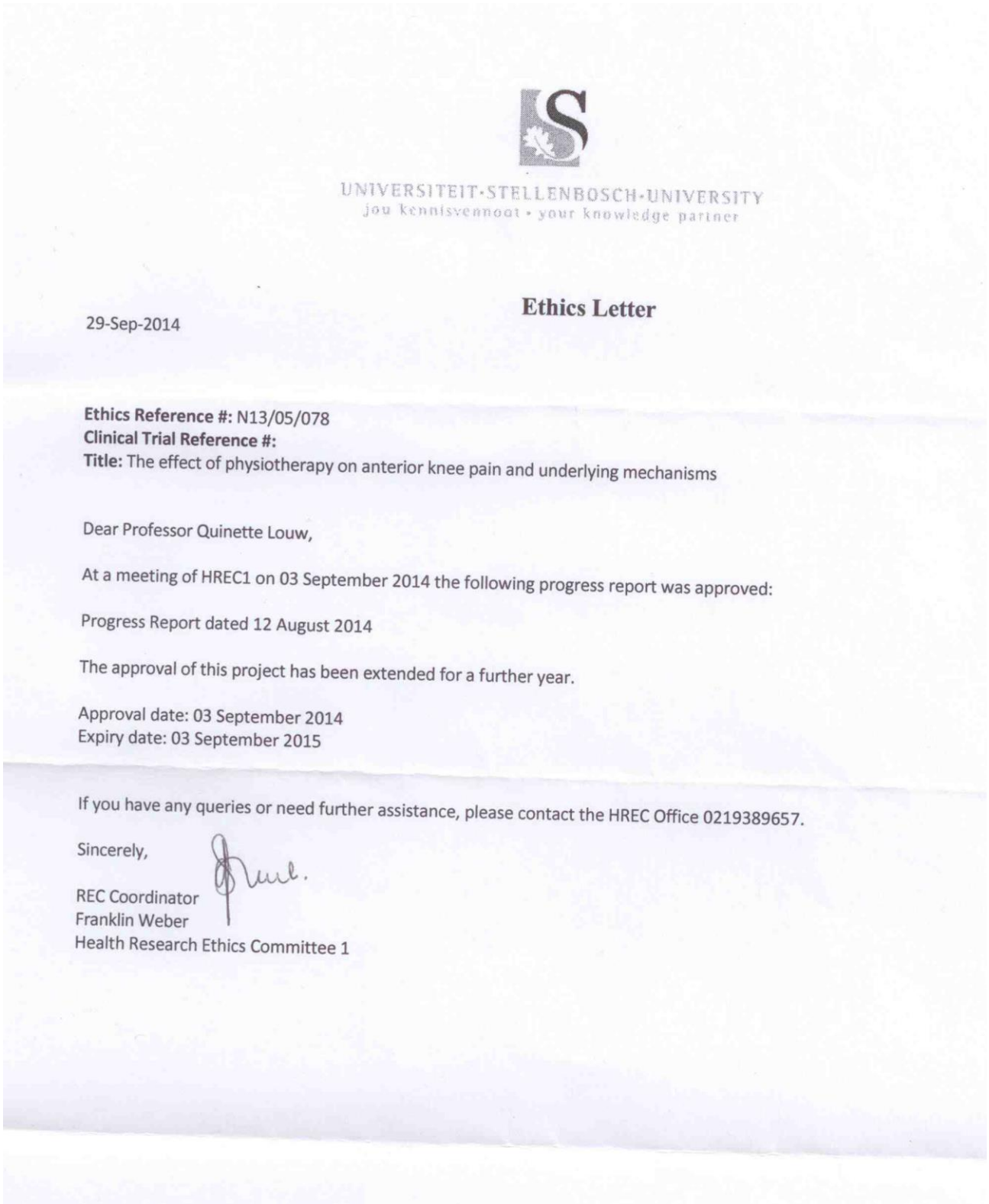
Appendix G: Letter of ethics approval



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Ethics Letter

29-Sep-2014

Ethics Reference #: N13/05/078
Clinical Trial Reference #:
Title: The effect of physiotherapy on anterior knee pain and underlying mechanisms

Dear Professor Quinette Louw,

At a meeting of HREC1 on 03 September 2014 the following progress report was approved:

Progress Report dated 12 August 2014

The approval of this project has been extended for a further year.

Approval date: 03 September 2014
Expiry date: 03 September 2015

If you have any queries or need further assistance, please contact the HREC Office 0219389657.

Sincerely,

REC Coordinator
Franklin Weber
Health Research Ethics Committee 1