A systematic review of the effect of open and closed kinetic chain exercises on the vastus medialis oblique and vastus lateralis muscles of patients with patellofemoral pain syndrome

Abstract

Objectives
The purpose of the present study is to review the existing literature regarding the response of the Vastus medialis oblique (VMO) and Vastus lateralis (VL) muscles of patients with Patellofemoral pain syndrome (PFPS) to open and closed kinetic chain exercises.

Search methods
A search was conducted for randomised and non-randomised controlled trials published by July 2016 and involving comparative analysis of exercise treatment with control groups or various exercise treatment types. The following resources were searched: the Cochrane Bone, Joint and Muscle Trauma Group and Cochrane Rehabilitation and Related Therapies Field specialised registers, the Cochrane Controlled Trials Register, The Physiotherapy Evidence Database (PEDro), MEDLINE, EMBASE, and CINAHL.

Data collection and analysis
Trials were excluded if they were not concerned with exercise therapy in individuals with PFPS. Thus, only nine out of 91 trials found were included and they all employed statistical techniques to assess the response of VMO and VL muscles to open and closed kinetic chain exercises.

Main results
The trials under review are too few in number and are inconsistent with regard to rehabilitation strategies and outcome assessment. They underline the necessity for reviewing RCT trials on a wider scale as the evidence they supply in support of use of open and closed kinetic chain exercises is insufficient. Trials have to be comparable in terms of participant traits, intervention and outcome assessment to improve the validity of the conclusions drawn. It was not possible to definitely say whether one intervention was better than another, because different interventions were implemented in the reviewed trials. Furthermore, future research should also include placebo-controlled trials to ascertain the efficiency of various interventions.

Keywords: the cochrane bone, cochrane rehabilitation, placebo-controlled trials, biomechanical nature

Abbreviations: VMO, vastus medialis oblique; VL, vastus lateralis; PED, physiotherapy evidence database

Introduction
The Patellofemoral pain syndrome (PFPS) is a Retro patellar or per patellar pain caused by Patellofemoral joint modifications of a physical and biomechanical nature. Individuals with painful knees often receive a diagnosis of PFPS which is worsened by performance of activities like stair climbing/descending, squatting or prolonged sitting with knees in a flexed position. This condition has a prevalence of 22/1000 person years and women, particularly those between 18 and 35 years of age Roush and Bay, 2012 are twice as likely to be affected compared to men. Moreover PFPS accompanies a quarter of knee injuries sustained during sports yet no comprehensive understanding has been achieved regarding how this condition develops and how it is classified, diagnosed and treated. However, many researchers have concurred that PFPS is not the outcome of just one, but several causative factors including excessive use, trauma, anatomical aspects, inadequate muscle functioning, and abnormal lower limb alignment. Additionally, quadriceps deficiency or atrophy, especially imbalanced movement of quadriceps components is considered the main biochemical factor underpinning PFPS development, although conclusive evidence has not been produced so far.

The vastus lateralis (VL) muscle supports the lateral movement of the patella while the vastus medialis muscle, especially the vastus medialis oblique (VMO), supports the medial patellar movement. The fibres of the VMO are angled almost horizontally (50-55°) with regard to the shaft of the femur serving more to stabilise the patella medially...
A systematic review of the effect of open and closed kinetic chain exercises on the vastus medialis oblique and vastus lateralis muscles of patients with patellofemoral pain syndrome

Coqueiro et al.

The research

8

Fehr et al.

5

Laprade et al.

DOI:

rather than contributing significantly to knee extension.\(^5\) Despite the fact that their efficiency is unclear exercises meant to strengthen the VMO are frequently prescribed to PFPS sufferers.\(^6\) Double-leg semi-squat with hip adduction and squats with concomitant squeezing of a ball between knees are two of the exercises commonly prescribed to rehabilitate PFPS. Nonetheless, as observed by;\(^7\) there is not enough objective evidence to confirm that such exercises are indeed efficient.

The exercises typically prescribed to strengthen the VMO can be classified into two categories, namely, open and closed kinetic chain exercises. One study reported that exercises meant to extend the knee at varying angles between 0° and 60° resulted in VMO activation.\(^8\) As explained by Fagan V\(^1\) exercises for knee extension pull the patella within the trochlear groove of the femur by the quadriceps and cranial slides and therefore are deemed to correct the imbalance between the VMO and VL that characterises PFPS and in this way they make patellar tracking more stable. Meanwhile, according to\(^9\) both open and closed kinetic chain exercises contributed to alleviation or prevention of PFPS. Despite the fact that their efficiency remains a matter of debate, open chain leg extension exercises are often recommended in clinical practice to engage the VMO.\(^10\) Open kinetic chain exercises involve moving just one joint with no weight bearing and a free distal extremity. By contrast closed kinetic chain exercises involve movement of more than one joint with weight bearing and a fixed distal extremity.\(^11\)

**Literature search**

Earlier reviews were searched in order to assess the comprehensiveness with which the subject under consideration has been investigated. Results suggested that the response of the VMO and VL muscles of PFPS patients to open or closed kinetic chain exercises was not addressed by any of the studies reviewed. Table 1.

**Table 1 Data extraction table**

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Publication details</th>
<th>The research question and purpose</th>
<th>Participant characteristics</th>
<th>Physiotherapy exercise modality</th>
<th>Outcome measurements function, pain, and qol</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fehr et al.(^24)</td>
<td>To analyse the therapeutic effects of the open kinetic chain (OKC) and closed kinetic chain (CKC) exercises to treat the patellofemoral syndrome (PFSD).</td>
<td>24 volunteers, bearers of the PFSD were randomly divided in two groups: group I (n=12) performed the OKC exercises; group II (n=12) performed the CKC exercises.</td>
<td>Open &amp; closed Chain exercises</td>
<td>The electromyographic signals (EMG) were collected using bipolar surface electrodes quantified by the root mean square (RMS) to measure the pain intensity upon the rest and while performing functional activities, the VAS and the Kujala scale were respectively applied</td>
<td>The results found in this study suggest that according to the conditions of the trial, the OKC and CKC exercises provoke no changes in the patterns of the EMG activation in the VMO and VL muscles.</td>
</tr>
<tr>
<td>2</td>
<td>Laprade et al.(^3)</td>
<td>Comparison of Five Isometric Exercises in the Recruitment of the Vastus Medialis Oblique in Persons With and Without Patellofemoral Pain Syndrome</td>
<td>19 female control subjects were 24 years, 165.8 cm and 58.9 kg, respectively. 8 female subjects with PFPS were recruited into the study. Were 24 years, 165.6 cm, and 60.9 kg respectively. Subjects performed two submaximal isometric contractions and one maximal isometric contraction</td>
<td></td>
<td></td>
<td>No significant differences in the EMG VM0: VL proportions were found between control subjects and those with patellofemoral syndrome.</td>
</tr>
<tr>
<td>3</td>
<td>Coqueiro et al.(^27)</td>
<td>To investigate the effect of hip adduction on the activity of the Vastus Medialis Obliquus (VMO) and Vastus Lateralis Longus (VLL) muscles during semisquat exercises.</td>
<td>Ten healthy subjects (age: 21.8±2.52 years old) Ten sedentary PFPS subjects (age: 23.2±2.65 years)</td>
<td>Double-leg semisquat exercise associated with hip adduction (DLSH-HA) isometric contraction &amp; double-leg semisquat (DLSH) exercise</td>
<td>Electromyographic muscle. The electrical activity of the VMO and VLL muscles was detected by active differential surface EMG electrodes, supplied by Lynx Electronics Technologies (Brazil).</td>
<td>There was no preferential VMO muscle activation,</td>
</tr>
</tbody>
</table>

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Table Continued

<table>
<thead>
<tr>
<th>Study</th>
<th>Authors</th>
<th>Design</th>
<th>Participants</th>
<th>Methods</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Santos et al.</td>
<td>Randomised controlled trial</td>
<td>Twenty women with PFPS (n=69)</td>
<td>Electrogoniometers to measure knee flexion/extension angles with respect to time, electromyography to detect VMO activity, and a standard Myo Trac biofeedback device was used (Premier Medical, Kent, WA).</td>
<td>Two flexible electromyography exercises emphasising selective activation and retraining of the VMO muscle relative to the VL muscle was undertaken by using a dual channel surface electromyographic biofeedback unit.</td>
</tr>
<tr>
<td>5</td>
<td>Syme et al.</td>
<td>Randomised controlled trial</td>
<td>Patients with PFPS (n=69)</td>
<td>Electromyographic onsets of the vastus medialis oblique (VMO) and functional Index Questionnaire (FIQ) were used to determine the effects of a weight-bearing rehabilitation program on quadriceps and hip abductor musculature.</td>
<td>The rehabilitation program consisted of weight-bearing exercises that focused on strengthening the quadriceps and hip abductor musculature.</td>
</tr>
<tr>
<td>6</td>
<td>Boling et al.</td>
<td>Randomised controlled trial</td>
<td>Twenty-eight subjects (14 controls, 14 experimental)</td>
<td>Electromyographic onsets of the vastus medialis oblique (VMO) and Functional Index Questionnaire (FIQ) were used to determine the effects of a weight-bearing rehabilitation program on quadriceps and hip abductor musculature.</td>
<td>Ratings of worst pain as measured with a 100-mm visual analog scale (VAS-W), Lysholm scale scores, and measurements of VMO morphology (including cross-sectional area [CSA] and volume) were obtained before and after the intervention.</td>
</tr>
<tr>
<td>7</td>
<td>Song et al.</td>
<td>Randomised controlled trial</td>
<td>Eighty-nine patients with PFPS (69 females)</td>
<td>Electromyographic onsets of the vastus medialis oblique (VMO) and Functional Index Questionnaire (FIQ) were used to determine the effects of a weight-bearing rehabilitation program on quadriceps and hip abductor musculature.</td>
<td>Participants were randomly assigned to 1 of 3 groups: hip adduction combined with leg-press exercise (LPHA group), leg-press exercise only (LP group), or no exercise (control group). Training consisted of 3 weekly sessions for 8 weeks.</td>
</tr>
</tbody>
</table>

The purpose of this study was to evaluate the amplitude and onset of electrical activation of the vastus medialis oblique (VMO), vastus lateralis longus (VLL) and vastus lateralis obliquus (VLO) during functional activities in individuals with patellofemoral pain syndrome (PFPS). The objective of this study was to determine the surplus effect of hip adduction on the VMO. To measure VMO activity, a standard Myo Trac biofeedback device was used (Premier Medical, Kent, WA). This study did not demonstrate that rehabilitation with selective VMO exercise significantly improves outcome above that provided by general open and closed chain strengthening exercises. Similar changes in pain reduction, functional improvement, and VMO hypertrophy were observed in both exercise groups.
A systematic review of the effect of open and closed kinetic chain exercises on the vastus medialis oblique and vastus lateralis muscles of patients with patellofemoral pain syndrome

Table Continued

| 8 | Kang et al. | This study aimed to examine the effects of closed kinetic chain exercise using electromyography (EMG) biofeedback for selective strengthening of the vastus medialis oblique (VMO) on patellofemoral joint pain and functional characteristics of patellofemoral joint muscles. The subjects of this study were 30 patellofemoral pain syndrome (PFPS) patients and they were equally and randomly assigned to a control group (I), a closed kinetic chain exercise group (II) and an EMG biofeedback closed kinetic chain exercise (III). A closed kinetic chain exercise group |
| 9 | Hwangbo | 20 young adults with an increased Q-angle, who were then divided into a squat group that received visual feedback (VSG, n=10) and a squat group that received no visual feedback (SG, n=10). Squat exercises with a maximum of 90° of knee flexion within a route marked on a mirror |

Current reviews

The focus of the review conducted by Almangoush et al. on considerations such as the attachment of the vastus medialis (VM) muscle to the patella and the extent of this attachment how long the distal VM tendon was and whether these aspects underpinned the aetiology of Patellofemoral conditions. A number of eight studies were obtained from electronic and manual search of works published in English and concerned with examination of how the distal VM attached to the patella based on cadaver dissection or radiography. According to the results in most cases the attachment of the distal VM was proximal or at the midpoint of the patella. Furthermore it was found that the distal VM attached to the patella in a proportion of 10% of its length and the distal VM tendon was between 1.4 and 3.5 cm long. However the insufficiency of comprehensive studies on this topic hindered formulation of conclusions as to whether these aspects contributed to Patellofemoral condition aetiology.

The review conducted by Hwangbo focused on determining whether preferential strengthening could be achieved through greater activation of the VMO compared to the VL by modifying how the joints of the lower limbs are oriented or how different muscles contract together. The review encompassed a number of twenty studies with an overall sample size of 387 participants. The results of most of these studies indicated that VMO was not preferentially activated over VL based on modification of lower limb joint orientation or muscle co-contraction. Furthermore, several notable shortcomings of methodology were distinguished. Therefore to address these shortcomings and accomplish a comprehensive exploration of the subject the authors suggested that future research must have a better design and include larger numbers of participants with patellofemoral joint problems. To the current researcher’s knowledge this topic has not been approached by any other previous study which means that the results of this study will be significant for both PFPS patients and for professionals in charge of exercise therapy.

The review question

The researchers do not know of any randomised controlled trials concerned with VMO and VL response to open and closed kinetic chain exercises among PFPS patients that have been systematically reviewed. Therefore the present study is the first to review randomised clinical trials in a thorough and systematic manner.

Objectives

A. To systematically evaluate how efficient open and closed kinetic chain exercises are in activating the VMO and VL muscles of PFPS patients
B. To compare how different open and closed kinetic chain exercises influence VMO and VL activity and therapeutic interventions
C. To identify what are the most efficient open and closed kinetic chain exercises.

Methods

A systematic review can be understood as a methodological tool with which the literature associated with a specific subject can be searched and examined to achieve a certain aim.\(^\text{14}\) Similarly,\(^\text{15}\) explained that the systematic review employs specific factors of identification, evaluation and compilation to scrutinise all published and unpublished works related to a topic. The systematic review is considered the ideal strategy for investigating randomised control trials (RCTs) because it helps to avoid bias in interpretation that direct selection of studies by the researcher may engender.

Search strategy

The study was undertaken an electronic search of relevant journals, books, conference proceedings and reference lists as well as a manual search with inclusion of all published and unpublished works written in English and related to the subject in question. Both abstracts and full texts were examined.

Criteria for inclusion in the study

The study will employ specific inclusion and exclusion criteria in order to ensure that the systematic review will yield interpretations and conclusions that are pertinent and objective. This is in keeping with\(^\text{16}\) who suggested that to obtain unbiased findings a review should only encompass works that demonstrate certain aspects or features. Thus the search in this study will be guided by the following criteria:

Study type

To accomplish the research goal the study design of randomised controlled trial (RCT) has been chosen so that the efficiency of therapeutic interventions can be assessed impartially.\(^\text{17}\) Because it selects and organises participants randomly the RCT is deemed the ‘gold standard’ in clinical research\(^\text{18},\text{19}\) and is underpinned by quantitative methodology since it is geared towards measuring outcomes with regard to intervention groups.

Types of participants

To be included in the review studies had to examine both male and female participants in the age range 18-40 years old suffering from PFPS in at least one lower limb.\(^\text{20}\)

Forms of interventions

Every study that employed conventional open and closed kinetic chain exercises for lower extremities and proprioceptive rehabilitation programs for the VMO and VL muscles was included in the review.

Outcome measures

As highlighted by\(^\text{21}\) the research outcome measures are highly important determining how reliable the findings are as well as how robust and valid the entire research is. For research to be considered valid it must be based on outcomes grounded in reliable data. The primary outcome measures employed in this systematic review are static postural control (SPC) and dynamic postural control (DPC) for PFPS patients. In addition, two flexible electrogoniometers are used to measure the flexion and extension angles of the knee in relation to time\(^\text{22}\) whilst heel and toe foot-switches for each foot enable the determination of gait stance and swing phases.

Exclusion criteria

Comments, letters, editorials, protocols, guidelines, abstracts, conference proceedings, review papers, unpublished papers such as university theses and dissertations, studies relying on animal models and studies written in languages other than English were all excluded from the review so as to make sure that every original work was critically evaluated.

Data collection and analysis

The study selection process

The subjectivity of the individual performing the selection process may skew the choice of studies included in the review. This issue can be avoided if a minimum of two reviewers undertake the process of selection once the relevant studies have been determined, so as to prevent bias and ensure the impartiality of the selection.\(^\text{23}\)

Study selection

As mentioned earlier the researcher was the only reviewer of the studies obtained from the search of the literature, owing to restrictions of time and resources. All studies that met the selection criteria were thoroughly read by the researchers to ensure their relevance with regard to the subject under investigation.

Data collection

According to\(^\text{24}\) representation of acquired data in a visual manner can facilitate the assessment of the selected studies. The standardised collection of data was undertaken in keeping with a number of criteria, including information related to publication, research question, research design, experiment techniques, randomisation, binding, information related to participants, such as inclusion and exclusion criteria and recruitment as well as findings related to intervention outcomes.

Data analysis and synthesis

As suggested by,\(^\text{25}\) meta-analysis can enable the measurement of the impact of open and closed kinetic chain exercises on the VMO and VL muscles. This is a statistical technique designed to synthesise data from several identical studies. The narrative method of systematic representation is employed to analyse and compare the research results in the event that identical studies are not available. Furthermore, adverse effects and withdrawal rates can be recorded as well, provided that the data allow it. If trials are non-uniform, then additional outcomes may be evaluated.

The process of search

The electronic databases AMED, CINAHL, the Cochrane database, EMBASE, ovid Medline, Physiotherapy Evidence Database (PEDro) and Pubmed were searched from their first issue to August 2016. The keywords used to structure the search were chosen based on their sensitivity rather than their specificity and encompassed “vastus medialis”, “vastus medialis obliquus”, “VMO”, “anatomy”, “vastus lateralis”, “VL”, “open kinetic chain exercise”, “closed kinetic chain exercise”, “exercise therapy” and “patellofemoral pain syndrome”. The keywords were deliberately non-specific so that the search would yield all the works of potential relevance. Furthermore the search of


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Results

Study selection

A number of 91 possible studies were obtained from the search of the electronic databases and the manual search of the references listed in every relevant article. Of these 39 studies were eliminated after the titles and abstracts were screened because they failed to satisfy the inclusion and exclusion criteria. Regarding the rest of 52 studies their full texts were downloaded and scrutinised and after the elimination of duplicates from different databases a number of nine full-text studies were obtained. These were again subject to appraisal with respect to the inclusion and exclusion criteria as shown in Figure 1. The nine RCTs obtained from the electronic and manual search for inclusion in the review were26–30 all from Brazil11,20,29,30 and11,22 both from the Republic of Korea.

Assessment of the quality of methodology

In accordance with11 the methodological quality was evaluated in order to make sure that there was good understanding of the research evidence and that there was satisfactory agreement between theoretical and practical aspects. The critical assessment instrument PEDro consisting of eleven items is useful for the measurement of theoretical and practical aspects. The critical assessment instrument PEDro consisting of eleven items is useful for the measurement of internal validity and recording of statistical measures and therefore it was applied to assess the quality of the research methodology of each selected study PEDro, 1999 Table 2.

Quality of evidence

The studies conducted by20,21,29,36 were demonstrated good quality (≥7), according to the cut-off points established earlier. Meanwhile the studies undertaken by27,29,32 deemed to be of moderate quality (≥5), whereas the studies by28 and11 were of poor quality (<4).

Summary and evaluation of the evidence

Compared individuals with and without PFPS in terms of VMO and VL activation based on five isometric exercises. The participants were all female and 24 years old, and of the total of 27 participants, 19 did not have PFPS whereas 8 had the condition. The participants were asked to perform two sub maximal isometric contractions and four maximal isometric knee extension contractions, whilst they were attached bipolar gold-plated electrodes to document the raw EMG signals. According to the results, there was no notable difference between the participants with and without PFPS with regard to EMG VMO or VL proportions. Nonetheless, the study was graded only a 3 on the PEDro scale of methodological quality because it did not apply randomisation.

Conducted an RCT on 69 participants with PFPS to investigate rehabilitation outcomes of interventions that involved retraining the quadriceps femoris element of the VMO and strengthening of the entire quadriceps femoris. To ensure that only the VMO muscle was activated and retrained and not the VL muscle, physiotherapy exercises were administered with a dual channel surface electromyography biofeedback unit. Two flexible electrogoniometers permitted the measurement of knee extension and flexion angles. However, as stressed by Rower PJ27 this approach was found to be valid and reliable only for people who did not suffer from PFPS. The findings did not confirm that selective VMO activation led to better outcomes compared to open and closed chain strengthening exercises.

The pragmatic nature of the applied interventions hindered an evaluation of the extent to which the different elements of the rehabilitation program were significant. In spite of this, studies employing just one intervention contradict clinical practice as physiotherapists typically employ more than one intervention strategy.34,35 Hence, it can be said that the nature of the employed interventions can contribute to make the results of a study more valid and more amenable to generalisation. Meanwhile a series of relevant issues were highlighted in the study as well.

Clinicians should not attribute greater importance to selective activation before the rehabilitation program is commenced especially in the case of individuals with chronic conditions whose participation is significantly restricted. This conclusion is derived from the fact that the study did not confirm that selective VMO activation was more effective compared to open and closed chain strengthening exercises in enhancing rehabilitation outcomes.36,37 Nevertheless, the study scored 9 on the PEDro scale with regard to methodological quality. A total of 28 participants in the age range 18–42 years old, of which 14 were assigned to the control group and 14 to the experimental group, were recruited by20 to examine how weight-bearing rehabilitation affected VMO and VL electromyography activity, pain and function. The rehabilitation strategy applied to the experimental group comprising five males and nine females with an average age of 24 years old consisted of weight-bearing exercises intended to alter muscle pain, function and activation patterns by balancing.

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Table 2 PEDro criteria

<table>
<thead>
<tr>
<th>PEDro criteria</th>
<th>1) Fehr et al.</th>
<th>2) Laprade et al.</th>
<th>3) Coqueiro et al. 2005</th>
<th>4) Santos et al.</th>
<th>5) syme et al.</th>
<th>6) Boling et al.</th>
<th>7) Song et al.</th>
<th>8) Kang et al.</th>
<th>9) Hwangbo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Eligibility criteria</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2. Random allocation</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>N/M</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>N/M</td>
</tr>
<tr>
<td>3. Concealed allocation</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>NO</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>N/M</td>
<td>Yes</td>
</tr>
<tr>
<td>4. Comparable baseline</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>5. Subjects blinded</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>6. Therapists blinded</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>7. Assessors blinded</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>8. Outcomes for 85% of initial participants</td>
<td>N/M</td>
<td>N/M</td>
<td>N/M</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9. Intention-to-treat analysis</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>10. Between group statistical comparison</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>11. Point &amp; variability measures</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Total score</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>9</td>
<td>6</td>
<td>10</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 3 Studies excluded from the review

<table>
<thead>
<tr>
<th>No.</th>
<th>The study</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Harrison et al.</td>
<td>No specification of muscles</td>
</tr>
<tr>
<td>2</td>
<td>Witvroue et al. (2003)</td>
<td>Focus on VMO and VL reflex response</td>
</tr>
<tr>
<td>3</td>
<td>IRISH et al.</td>
<td>Inclusion of healthy individuals</td>
</tr>
<tr>
<td>4</td>
<td>Hashmiy et al (2011)</td>
<td>Rules of conduct</td>
</tr>
<tr>
<td>5</td>
<td>Ismail et al.</td>
<td>No specification of muscles</td>
</tr>
<tr>
<td>6</td>
<td>Chang et al.</td>
<td>Inclusion of healthy females</td>
</tr>
<tr>
<td>7</td>
<td>Lam.</td>
<td>Not RCT</td>
</tr>
<tr>
<td>8</td>
<td>Miao.</td>
<td>Cross-sectional study</td>
</tr>
<tr>
<td>9</td>
<td>O’Sullivan et al.</td>
<td>Lack of a control group</td>
</tr>
<tr>
<td>10</td>
<td>Pattyn et al.</td>
<td>Case-control study Use of MRI for assessment of VMO size in individuals with PFPS</td>
</tr>
<tr>
<td>11</td>
<td>Tang.</td>
<td>Case-control study</td>
</tr>
</tbody>
</table>


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Discussion

Analysis of reviewed studies

Closed kinetic chain and weight-bearing exercises (e.g. double-leg squat, leg-press and lung exercises) were administered by Irish SE\textsuperscript{39} as well as\textsuperscript{27} with the purpose of strengthening the VMO muscle. The results they obtained provided evidence that these types of exercises are effective in activating the VMO and VL muscles. Furthermore, performance of squat exercises (i.e. mini-squat, semi-squat, wall-sit and wall-slide exercises) together with hip adduction enhanced quadriceps activation not only in participants without PFPS but also in those with PFPS. An additional observation reported by Coqueiro KRR\textsuperscript{72} was that closed kinetic chain exercises augmented VMO activation more than VL activation. By contrast, performance of closed kinetic chain exercises alongside weight-bearing exercises led to an increase in pulling strength and intra-articular pressure, worsening PFPS symptoms.

On the other hand\textsuperscript{40} did not observe activation in the VMO that was significant enough to augment patellar tracking, therefore concluding that open kinetic chain exercises did not have a marked impact on PFPS rehabilitation. By contrast\textsuperscript{41} stated that application of sling open chain knee extension (SOCKE) exercise in conjunction with sling exercise therapy (SET) intensified VMO activity compared to VL activity. Most of the studies that were reviewed compared the responses of the VMO and VL muscles of participants with PFPS\textsuperscript{42} to open and closed kinetic chain exercises, but none of them compared experimental and placebo control groups. This may be explained in terms of the ethical issues associated with denial of therapy or the problems posed by the development of an effective physiotherapy placebo. In spite of this however the study findings lend credence to the efficiency of open and closed kinetic chain exercises in alleviating pain caused by PFPS.

The limited sample sizes meant that effects could be distinguished between the research groups only if they were sufficiently pronounced. Furthermore, intervention effects could not be monitored in the long-term in many experimental group participants who responded positively to the intervention because a proportion of 48% of them withdrew from the research after twelve months. Hence, the credibility of the results is questionable. Even so both open and closed kinetic chain exercises were found by many of the reviewed studies to be beneficial for improving pain and function in the long-term. Even though physiotherapy was found to determine a reduction in pain no definitive evidence was produced regarding the greater efficiency of one intervention type over another. Nevertheless there can be no doubt that of the various strengthening methods, muscle function benefitted the most from open and closed kinetic chain exercises Table 3.

The lack of agreement between the findings of the different reviewed studies may be due to discrepancies in methodology. Another potential cause is the fact that the open and closed kinetic exercises were not tailored to each participant according to individual problems (e.g. dysfunctional muscle motor control or excessive tightness of soft tissues surrounding the Patellofemoral joint) but instead were applied in a standardised manner, with potential adverse implications for intervention outcome. This second cause ought to be inspected further with clinical trials. Trials that are more scientifically sound should be undertaken to determine how efficient the applied interventions were. According to current evidence an intervention approach integrating education, stretching and quadriceps\textsuperscript{43} strengthening and application of soft corrective foot orthoses should be adopted to treat PFPS successfully.

Shortcomings

Two limitations of methodology are demonstrated by the present systematic review. The first limitation is that owing to a desire to ensure quality the review did not include data sources that were not published (i.e. “grey literature”) but only studies that were peer-reviewed. Hence, this might have given rise to a publication bias that could have affected the results obtained. The other limitation is that to save costs the review did not include studies written in languages other than English.\textsuperscript{44}

Significance for practice

It is clear that pain associated with PFPS benefits from open and closed kinetic chain exercises at least in the short-term however it is still unclear whether the efficiency of these exercises surpasses that of exercises that can be undertaken at home. Therefore, it is important to determine the factors related to PFPS development to devise efficient interventions that can be adapted to the requirements of each PFPS patient. Future research should then focus on the formulation of case-specific rehabilitation interventions and reliable measures of outcome evaluation.

Conclusion

The trials under review were too few in number and were inconsistent with regard to rehabilitation strategies and outcome assessment. They underline the necessity for reviewing RCT trials on a wider scale as the evidence they supplied in support of use of open and closed kinetic chain exercises was insufficient. Trials have to be comparable in terms of participant traits, intervention and outcome assessment to improve the validity of the conclusions drawn. Additionally it was not possible to definitely say whether one intervention was better than another because different interventions were implemented in the reviewed trials. Furthermore, future research should also include placebo-controlled trials to ascertain the efficiency of various interventions.

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Conflict of interest

The author declares no conflict of interest.

References

6. Powers CM. Patellar kinematics, part I: the influence of vastus muscle

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A systematic review of the effect of open and closed kinetic chain exercises on the vastus medialis oblique and vastus lateralis muscles of patients with patellofemoral pain syndrome


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