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The Effectiveness of Pre-operative Exercise Physiotherapy Rehabilitation on the Outcomes of Treatment following Anterior Cruciate ligament Injury: A Systematic Review

Abstract

Objective: To evaluate the effectiveness of pre-operative exercise physiotherapy rehabilitation on the outcomes of treatment following anterior cruciate ligament injury.

Methods: The following databases were searched: PubMed, Ovid, The Cochrane Library and Web of Science. Studies published between the inception of the databases and December 2015 were sought using appropriate keywords in various combinations. This search was supplemented with a manual search of the references of selected studies. Studies were assessed for methodological quality using the Physiotherapy Evidence Database scale.

Results: A total of 500 studies were identified, of which eight studies met the inclusion criteria and were included in the present review. The average Physiotherapy Evidence Database score for the studies included was 5.8, which reflects an overall moderate methodological quality.

The eight studies investigated a total of 451 subjects of which 71% (n=319) were males. The age of the participants in the eight studies ranged from 15 to 57 years. The duration of the intervention in the studies ranged from 3 to 24 weeks. This review found that pre-operative physiotherapy rehabilitation is effective for improving the outcomes of treatment following anterior cruciate ligament injury, including increasing knee-related function and improving muscle strength. However, whilst there was a significant improvement in quality of life from baseline following intervention, no significant difference in quality of life was found between the control and intervention groups.

Conclusions: There is evidence to suggest that pre-operative physiotherapy rehabilitation is beneficial to patients with anterior cruciate ligament injury.

Keywords: Physical Therapy, Pre-operative Exercise, Outcome Assessment (Health Care), Anterior Cruciate Ligament Injury, Quality of Life

Introduction

Internal knee injuries account for nearly 45% of sports related injuries, with anterior cruciate ligament injury being the most prevalent structure damaged ¹. Anterior cruciate ligament injury is associated with pain, instability of the joint, muscle weakness, functional limitation, poor quality of life, and an increased risk of knee-related osteoarthritis ^{2,3}. Anterior cruciate ligament reconstruction surgery is the main treatment for anterior cruciate ligament injuries ⁴. Over 200 thousand anterior cruciate ligament reconstruction surgeries take place each year in the United States, which costs more than \$3 billion annually^{1,5}. Pre-operative physiotherapy, such as an exercise rehabilitation programme, is often performed to prepare the knee for reconstruction surgery and to maximise the outcomes of rehabilitation ^{6,7,8}. Physiotherapy rehabilitation prior to anterior cruciate ligament surgery is used to increase muscle strength and functional ability ^{9,10}. In addition, pre-operative physiotherapy can reduce the risk of pivot shift episodes, which can often cause progressive joint damage, as well as facilitate recovery after reconstruction ¹¹.

During the 1980s, the potential of pre-operative physiotherapy to restore knee function was first suggested by Noyes et al. ¹⁰ yet there is no standardised rehabilitation approach for patients with this injury. Whilst there are a number of clinical trials that have investigated the effectiveness of pre-operative rehabilitation on the outcomes (pain, quality of life, range of motion, muscle strength and function) of treatment following anterior cruciate ligament injury there is a lack of consensus in these findings. Therefore, the aim of this systematic review was to examine the current level of

evidence in relation to the effectiveness of pre-operative exercise physiotherapy rehabilitation on the outcomes of treatment following anterior cruciate ligament injury.

Methods

A systematic review was undertaken following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines¹². The following electronic databases were searched: PubMed, OVID (AMED, MEDLINE), The Cochrane Library (Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials (CENTRAL), Cochrane Methodology Register), and Web of Science (science and social science citation index). Studies published between the inception of the databases and December 2015 (completion date of the search) were sought. The keywords used were: 'anterior cruciate ligament injury' 'pre-operative rehabilitation', 'pre-operative exercise', 'pre-operative protocol', and 'quality of life'. These keywords were then combined to refine the literature search and focus the review to the aim of the study (Appendix 1).

Articles searched were those conducted on human patients and published in English, and 'randomised controlled trial' was used as a filter for the search. The reference lists of the selected articles were also checked manually for any relevant studies that may not have been available electronically. The search strategy was complemented by a manual search of selected journals: Archives of Physical Medicine and Rehabilitation, British Medical Journal, Clinical Rehabilitation, Journal of Sport Rehabilitation, Physical Therapy, New England Journal of Medicine, the American Journal of Sports Medicine,

the Journal of Bone and Joint Surgery, International Scholarly Research Network Rehabilitation, Orthopaedic Journal of Sports Medicine and Physiotherapy Research International, to identify any missing relevant literature.

Studies were included if:

- They were randomised controlled trials
- They were in the English language
- They included human subjects with unilateral anterior cruciate ligament injury
- Pre-operative exercise physiotherapy rehabilitation was used to treat the patients

Studies were excluded if they were:

- On bilateral anterior cruciate ligament injuries

The Physiotherapy Evidence Database (PEDro) scale was used to assess the quality of methodology applied in the selected studies^{1,5,13,14,15,16,17,18}. Two reviewers (SA and GY) applied the scale to the studies and a high level of agreement was achieved (89%). A consensus method was used where there was disagreement, and an independent reviewer (FF) was consulted to make the decision regarding the final score and the inclusion of the article in the review.

The Physiotherapy Evidence Database scale is an 11 item scale with the first item assessing the external validity of the trial. Usually, this item is not included in the assessment of study; hence, the assessment was based on items 2 to 11 in the present study as recommended by Maher et al¹⁹ and has been previously used elsewhere²⁰.

These items were scored equally as 1 for yes and 0 for no. Studies with a Physiotherapy Evidence Database score of 0 to 4 were considered to be of poor methodological quality. Scores of 5 or 6 were considered to be of moderate quality, and those with scores of 7 and above were considered to have high methodological quality¹⁹. Three items on the Physiotherapy Evidence Database scale refer to blinding procedures. However, it is acknowledged that it is difficult to blind patients and therapists delivering physiotherapy interventions²¹, therefore, the maximum score that can be achieved by the studies included in this review was 8 out of 10.

Two reviewers (SA and GY) extracted data from the studies that fulfilled the inclusion criteria by independently using a data extraction form. To ensure that no significant information was omitted from the studies, the following were recorded during data extraction: author information, date and place of publication, sample information, drop outs, types and duration of intervention, outcome measures used, patient assessment and follow-up period, results and any other comments specific to each study (Table 1). Due to the small sample sizes and the heterogeneity in the outcomes assessed in the studies, a meta-analysis or statistical assessment of the outcomes was not performed^{22,23}. The applicability, reliability and validity of the studies were assessed using the randomised controlled trials checklist provided by the Critical Appraisal Skills Programme²⁴. The outcomes that were assessed included pain, quality of life, physical knee function, swelling, range of motion, muscle strength and functional activity.

Results

The results are reported based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses¹² guidelines with descriptive and narrative findings. Based on electronic and manual searches using the keyword search strategy, a total of 500 studies were identified (PubMed, 156; Ovid, 118; Web of Science, 220; Cochrane Library, 4; manual search, 2). After removing duplicates, applying the inclusion criteria and abstract screening, eight studies were found to satisfy these criteria (Figure 1). These eight studies were included in the review (Table 1).

The eight studies^{1,5,13,14,15,16,17,18} accepted for inclusion in the systematic review were then assessed for quality. The methodological quality of the studies included ranged from 3 to 7 out of 10 (Table 2). The mean score of the studies was 5.8, which reflects an overall moderate methodological quality. One study was of a low methodological quality¹, four were of moderate quality^{14, 15, 17,18} and three were of high quality^{5,13,16}. Intention-to-treat analysis was used in two studies^{5,13}. Three studies^{1,13,14} failed to report a concealment of treatment employed. The outcome assessor was blinded to the intervention in two studies^{13,16}. All the studies included reported that participants were randomised and reported the methods used for randomisation.

The eight studies investigated a total of 451 subjects, of which 71% (n = 319) were male participants. One study¹⁶ included only male participants (n = 23). The age of the participants in the eight studies ranged from 15 to 57 years. There were 36 dropouts in the trials. The reasons for dropping out included; fractures and other injuries that could interfere with the rehabilitation, the anterior cruciate ligament was not completely torn,

the treatment schedule was not maintained. The average number of participants in the treatment group after randomisation was 28 (range 9-59), with two studies having intervention groups containing more than 30 subjects^{5,15}.

Figure 1 around here

Table 1 around here

Table 2 around here

Pre-operative rehabilitation protocols were different in their content, duration and frequency of intervention. The average duration of the pre-operative intervention was 14 weeks (range 3-24 weeks)^{1,5,13,14,15,16,17,18}. Two studies did not report the frequency of treatment^{5,15}, however, for the remaining six studies^{1,13,14,16,17,18}, the average frequency of treatment was three times per week (range 2-4 times per week). The content of the pre-operative intervention consisted of: quadriceps and/or hamstring strengthening exercises^{1,5,13,14,15,16,17,18}; proprioception and/or balance training^{1,5,13,14,15,16,17,18}; gait re-education^{5,15, 18}; treatment to increase range of motion^{17,18}; functional specific rehabilitation^{17,18} and plyometrics¹⁷.

Several outcome measures were used to assess the effectiveness of pre-operative exercise physiotherapy rehabilitation. Pain was used as an outcome in three studies^{5, 15, 17}. No significant difference was found in patient reported pain between the intervention and control groups in any of the studies.

Physical function (in recreational or sports activities) was used as an outcome in seven of the eight^{5,13,14,15,16,17,18} studies. Two studies found a significant improvement in physical function in the intervention group compared to the control^{13,16}. Beard et al.¹³ reported greater physical function in the group following a rehabilitation programme designed to enhance proprioception and hamstring reflexes compared to the group that received a programme designed to improve muscle strength. Shaarani and colleagues¹⁶, found a significant increase in function from baseline to pre-operatively and at 12 weeks postoperatively, in the intervention group who received pre-operative physiotherapy rehabilitation compared to the control group which received no pre-operative physiotherapy intervention. Five studies found no significant difference in physical function between the groups^{5,14, 15, 17, 18}.

Quality of life was examined in three studies^{5,15,18} using a subscale of the Knee Injury and Osteoarthritis Outcome Score. Whilst there was a significant improvement in quality of life from baseline following intervention in both groups, none of the studies reported any significant difference in quality of life between the control and intervention groups.

Range of motion was used as an outcome in only one study¹⁷. There was no significant difference in range of motion between the two rehabilitation programmes using open and closed kinetic chain exercises.

Muscle (quadriceps and/or hamstring) strength and function were measured in four studies using a Biodex isokinetic dynamometer¹⁷, a Cybex isokinetic dynamometer¹⁶, or

a Kin-Com isokinetic dynamometer^{1,14}. Tagesson et al.¹⁷ reported that the intervention group had greater quadriceps muscle strength, however, no other significant differences in strength were found. Hartigan et al.¹ found that quadriceps strength increased in both groups, although there was no significant difference between the groups. However, they did find that quadriceps strength and knee excursions were more symmetrical 6 months postoperatively in the intervention group that received perturbation training and progressive quadriceps strength training than the control group who received strength training alone. The remaining two studies^{14,16} found no significant difference in muscle strength between the intervention and control groups.

The outcomes of knee-related symptoms, including swelling, were measured in four studies^{5,15,17,18}. No significant differences in symptoms between the control and intervention groups were found. Fitzgerald et al.,¹⁴ examined the effect of perturbation training on episodes of giving way of the knee. They found that a greater number of subjects in the control group had increased episodes of giving way ($p < 0.05$).

Discussion

Despite the range of pre-operative approaches used in the studies examined in this review, this study found that pre-operative physiotherapy rehabilitation is effective for improving the outcomes of treatment following anterior cruciate ligament injury. Furthermore, the diversity of approaches used in this review reflects the nature of pre-

operative physiotherapy in clinical practice in relation to this patient population and as such, enhances the clinical validity of the findings.

Of the eight studies include in this review, only Shaarani et al. ¹⁶ did not include pre-operative physiotherapy intervention for both groups, with the control group receiving no intervention. They found significant improvements in function and physical performance in the intervention group following pre-operative physiotherapy compared to the control group¹⁶.

All of the seven remaining studies included pre-operative physiotherapy exercise rehabilitation programmes for both the intervention and control groups^{1,5,13,14,15,17,18}. All seven studies showed improvements in function in both groups following pre-operative rehabilitation programmes. Of these studies, five found significant improvements in the intervention group compared to the control group in a range of outcomes, including: function, strength, and reflex hamstring contraction latency^{1,13,14,16,17}. In the studies by Frobell et al. ^{5,15}, a strategy of rehabilitation plus early anterior cruciate ligament reconstruction was not more effective at five years than a strategy of initial rehabilitation with the option of having a later anterior cruciate ligament reconstruction. Furthermore, in using the second approach, 50% of patients avoided the need for surgery with no implications on clinical outcomes in the intervention group¹⁵.

The average duration of the pre-operative intervention was 14 weeks (range 3-24 weeks) ^{1,5,13,14,15,16,17,18} with the frequency of sessions ranging between 2 – 4 sessions

per week^{1,13,14,16,17,18}. Thus, on average, patients received a total of 27 pre-operative treatment sessions^{1,13,14,16,17,18}. However, this number of treatment sessions is resource intensive and in the current economic climate, with healthcare budgets under increasing financial pressure, the clinical applicability of this may be questioned.

The Physiotherapy Evidence Database scores for seven of the eight papers included in the review ranged from 5 - 7, which indicates that they are of moderate to high methodological quality¹⁹; one study was of low methodological quality¹. There were a number of methodological flaws in the eight selected studies. The sample sizes for the studies included in the review were small, ranging from 23 to 121, with some of the studies not reporting how sample size was determined, hence limiting the external validity of their findings. In addition, whilst all the studies reported their randomisation procedures, there was no blinding of therapists who administered the therapy in any study, and only two studies reported blinding of all assessors who measured at least one key outcome^{13,16}, with only one study reporting blinding of the subjects¹³. This may have increased the risk of bias in these studies. However, it is acknowledged it may not be possible to blind some of the individuals, such as the therapist or patient, in a clinical trial. Furthermore, some important outcomes such as quality of life was not assessed in majority of the studies, except Frobell et al.^{5,15} and Thomeé et al.¹⁸. In addition, range of motion was examined in only one study¹⁷. Thus, further research is needed to assess the effectiveness of pre-operative physiotherapy rehabilitation on these outcomes of treatment following anterior cruciate ligament injury.

This systematic review has certain limitations. It included only studies published in English and, therefore, there is a possibility that relevant literature published in other languages may have been excluded. In addition, this review has included only published articles, which may have resulted in some data being missed due to publication bias.

To our knowledge, this is the first systematic review that has been undertaken to investigate the effectiveness of pre-operative rehabilitation for improving the outcomes of patients with anterior cruciate ligament injury undergoing reconstruction. This review has found that pre-operative rehabilitation is effective for these patients. Clinicians are to be aware of these findings as pre-operative rehabilitation may be of value to patients with this condition. In addition, the observed findings provide justification for continued use of pre-operative rehabilitation programme for these patients.

Clinical Message

- **Findings:** Pre-operative rehabilitation is effective for improving the outcomes of patients with anterior cruciate ligament injury undergoing reconstruction.
- **Implications:** Pre-operative rehabilitation may be of value to patients undergoing anterior cruciate ligament reconstruction. The continued use of pre-operative rehabilitation programme for patients undergoing this procedure is justified by the findings of this study.

References

1. Hartigan E, Axe MJ, Snyder-Mackler L. Perturbation training prior to ACL reconstruction improves gait asymmetries in non-copers. *Journal of Orthopaedic Research*. 2009;27: 724-9.
2. Arangio GA, Chen C, Kalady M, Reed JF III. Thigh muscle size and strength after anterior cruciate ligament reconstruction and rehabilitation. *Journal of Orthopedic and Sports Physical Therapy*. 1997;26:238-43.
3. Shaarani SR, Moyna N, Moran R, O'Byrne JM. Rehabilitation: the void in the management of anterior cruciate ligament injuries- a clinical review. *International Scholarly Research Notices*. 2012;938974. <http://dx.doi.org/10.5402/2012/938974>
4. Kowalchuk DA, Harner CD, Fu FH, Irrgang JJ. Prediction of patient-reported outcome after single-bundle anterior cruciate ligament reconstruction. *Arthroscopy*. 2009;25:457-63.
5. Frobell RB, Roos EM, Roos HP, Ranstam J, Lohmander LS. A randomized trial of treatment of acute anterior cruciate ligament tears. *The New England Journal of Medicine*. 2010;363:331-42.
6. Keays SL, Bullock-Saxton JE, Newcombe P, Bullock MI. The effectiveness of a pre-operative home-based physiotherapy programme for chronic anterior cruciate ligament deficiency. *Physiotherapy Research International*. 2006;11:204-18.
7. Kvist J, Gillquist J. Sagittal plane knee translation and electromyographic activity during closed and open kinetic chain exercises in anterior cruciate ligament-deficient patients and control subjects. *The American Journal of Sports Medicine*. 2001;29:72-82.
8. Mikkelsen C, Werner S, Eriksson E. Closed kinetic chain alone compared to combined open and closed kinetic chain exercises for quadriceps strengthening after anterior cruciate ligament reconstruction with respect to return to sports: a prospective matched follow-up study. *Knee Surgery Sports Traumatology Arthroscopy*. 2000;8:337-42.
9. Beynon BD, Johnson RJ, Abate JA, Fleming BC, Nichols CE. Treatment of anterior cruciate ligament injuries. Part 1. *The American Journal of Sports Medicine*. 2005;33:1579-1602.
10. Noyes F, Mooar B, Matthews D, Butler D. The symptomatic anterior cruciate-deficient knee. Part 1. *Journal of Bone and Joint Surgery*. 1983;65A:154-62.
11. Tegner Y, Lysholm J, Lysholm M, Guilloquist J. Strengthening exercises for old cruciate ligament tears. *Acta Orthopaedica Scandinavia*. 1986; 57:130-4.
12. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Phys Ther*. 2009;89(9):873-880.

13. Beard DJ, Dodd CAF, Trundle HR, Simpson AHRW. Proprioception enhancement for anterior cruciate ligament deficiency: a prospective randomized trial of two physiotherapy regimes. *The Journal of Bone and Joint Surgery*. 1994;76-B:654-9.
14. Fitzgerald GK, Axe MJ, Snyder-Mackler L. The efficacy of perturbation training in nonoperative anterior cruciate ligament rehabilitation programs for physically active individuals. *Physical Therapy*. 2000;80:128-40.
15. Frobell RB, Roos HP, Roos EM, Ranstam J, Lohmander LS. Treatment for acute anterior cruciate ligament tear: five year outcome of randomised trial. *BMJ*. 2013;346: f232.
16. Shaarani SR, O'Hare C, Quinn A, Moyna N, Moran R, O'Byrne JM. Effect of prehabilitation on the outcome of anterior cruciate ligament reconstruction. *The American Journal of Sports Medicine*. 2013;41:2117-27.
17. Tagesson S, Öberg B, Good L, Kvist J. A comprehensive rehabilitation program with quadriceps strengthening in closed versus open kinetic chain exercise in patients with anterior cruciate ligament deficiency: a randomized controlled trial evaluating dynamic tibial translation and muscle function. *The American Journal of Sports Medicine*. 2008;36:298-307.
18. Thomeé P, Währborg P, Börjesson M, Thomeé R, Eriksson BI, Karlsson J. A randomized, controlled study of a rehabilitation model to improve knee-function self-efficacy with ACL injury. *Journal of Sport Rehabilitation*. 2010;19:200-13.
19. Maher CG, Sherrigton C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. *Physical Therapy*. 2003;83:713-21.
20. Behm DG, Muehlbauer T, Kibele A, Granacher, U. Effects of Strength Training Using Unstable Surfaces on Strength, Power and Balance Performance Across the Lifespan: A Systematic Review and Meta-analysis. *Sports Med*. 2015;45(12):1645-69. doi: 10.1007/s40279-015-0384-x.
21. Hicks C. *Research methods for clinical therapists: applied project design and analysis*. Edinburgh: Churchill Livingstone;2009.
22. O'Rourke K, Detsky AS. Meta-analysis in medical research: strong encouragement for higher quality in individual research efforts. *Journal of Clinical Epidemiology*. 1989;42:1021-1026.
23. Palmer S, Bailey S, Barker L, Barney L, Elliott A. The effectiveness of therapeutic exercise for joint hypermobility syndrome: a systematic review. *Physiotherapy*. 2014;100,3:220–227 <http://dx.doi.org/10.1016/j.physio.2013.09.002>

24. Critical Appraisal Skills Programme (CASP) (2013). Randomised Controlled Trials Checklist 31.05.13: 11 questions to help you make sense of a trial. [Online] http://media.wix.com/ugd/dded87_ffa8e3161f58d3125d4338285081851e.pdf
Published 2013. Accessed May 9 2014

TABLE 1. Summary of data from studies that satisfied the selected criteria for inclusion

No	Authors, year, origin of study	Sample Size (drop-outs)	Patient characteristics	Intervention/control	Outcome measures	Patient assessment / follow-up	Results/comments (PEDro scale total score)
1	Beard et al. 1994; UK	50 (7)	<ul style="list-style-type: none"> - 18-35 years old; mean = 25 - Active - Recreational sports person 	<p>Control group:</p> <ul style="list-style-type: none"> - Quadriceps and hamstring muscles strengthening exercises (Open kinetic chain); group T <p>Intervention group:</p> <ul style="list-style-type: none"> - Quadriceps and hamstring muscles strengthening exercises (Closed kinetic chain); group P -Proprioception enhancement/training -12 weeks (twice weekly) for one hour. 	<p>-Knee function; using The validated functional scoring scale of Lysholm and Gillquist.</p> <p>-Proprioception; using The Vicon Interfaced Knee Displacement Equipment (VIKDE)</p>	<ul style="list-style-type: none"> -Baseline -12-weeks after physiotherapy course. 	<p>After treatment, both groups had a reduction in reflex hamstring contraction latency (RHCL) and an increase in functional score. The RHCL score in group P was higher than in group T (40ms, SD 30; 14ms, SD 35 respectively, $p < 0.05$) and the functional score in group P was greater than in group T (29.4, SD = 15; 11.2, SD = 15 respectively, $p < 0.005$).</p> <p>(PEDro score: 7/10; High quality)</p>
2	Fitzgerald et al. 2000; USA	28 (2)	<ul style="list-style-type: none"> - 15-57 years old, mean = 28 - Active - Recreational sports person 	<p>Control group:</p> <ul style="list-style-type: none"> - Strengthening exercises - Functional rehabilitation - Open and closed kinetic chain exercises <p>Intervention group:</p> <ul style="list-style-type: none"> - Strengthening exercises - Functional rehabilitation - Open and closed kinetic chain exercises - Balance training 	<p>-Knee Outcome Survey's Activities of Daily Living Scale (ADLS) and Sports Activity Scale</p> <p>-A global rating of knee function, scores on a series of single-limb hop tests.</p> <p>-Measurements of maximum isometric quadriceps femoris muscle force output; using a Kin-Com II dynamometer.</p> <p>-Passive anterior knee laxity measurement; Using KT-2000</p>	<ul style="list-style-type: none"> -Baseline -Post treatment -6 months post treatment. 	<p>More subjects had unsuccessful rehabilitation in the control group (7 out of 14) compared with the perturbation group (1 out of 12) (chi-square analysis: $\chi^2 = 5.27$, critical value=3.84, $p < .05$).</p> <ul style="list-style-type: none"> - There was a within-group 3 time interaction for the ADLS, global rating of knee function, and crossover hop test scores. These scores decreased from post-training to the 6-month follow-up for the standard group. - There were no differences between the mean hop scores (crossover and timed hop tests) for the control and intervention groups pre- and post-intervention ($p > 0.05$).

				<p>-5 weeks, 2-3 sessions per week (10 sessions)</p> <p>Duration of sessions not reported.</p>			(PEDro score: 5/10; Moderate quality)
3	Frobell et al. 2010; Sweden	121 (0)	<ul style="list-style-type: none"> - 18-35 years old; mean = 26 - Active - Recreational sports person 	<ul style="list-style-type: none"> - Gait rehabilitation - Quadriceps and hamstring muscles strengthening exercises - Balance and coordination training <p>Both control and intervention groups received the same exercises with delayed surgery for intervention group</p> <p>- 24 weeks</p> <p>Frequency and duration of sessions not reported</p>	<p><i>-Pain, symptoms, difficulty in sports and recreational activities and quality of life;</i> using (KOOS) score <i>- Physical component and mental component; using</i> (SF-36) survey <i>-ACL insufficiency;</i> using Tegner activity scale (TAS) questionnaires</p>	<p>-Baseline -3 months -6 months -12 months -24 months</p>	<p>The absolute change in mean KOOS score from baseline to 2 years was not significant (mean scores, 39.2 (control) and 39.4 (intervention); absolute difference, 0.18; 95% confidence interval, -6.5 to 6.8; $p = 0.96$, adjusted for baseline KOOS score). There were no significant differences between the two treatment groups with respect to outcomes.</p> <p>-More patients avoided the need for surgery with no implications on clinical outcomes in the intervention group.</p> <p>-No significant difference between mean scores for secondary outcomes for the first two years due to the intervention including pain ($p = 0.87$), function in daily living ($p = 0.68$) and sport ($p = 0.95$) and quality of life ($p = 0.28$).</p> <p>(PEDro score: 7/10; High quality)</p>
4	Frobell et al. 2013; Sweden	121 (1)	<ul style="list-style-type: none"> - 18-35 years old; mean = 26 - Active - Recreational sports person 	<ul style="list-style-type: none"> - Gait rehabilitation - Quadriceps and hamstring muscles strengthening exercises - Balance and coordination training 	<p><i>-Pain, symptoms, difficulty in sports and recreational activities and quality of life;</i> using (KOOS) score <i>- Physical component and mental component; using</i></p>	<p>-Baseline -5 years follow up</p>	<p>No significant differences between groups were seen in KOOS, mean difference (95% CI) 1.5 ($p = 0.45$), any of the KOOS subscales ($p \geq 0.12$), SF-36 ($p \geq 0.34$), Tegner activity scale ($p = 0.74$), or incidence of radiographic osteoarthritis of the index knee ($p = 0.17$).</p>

				<p>Both control and intervention groups received the same exercises with delayed surgery for intervention group</p> <p>- 24 weeks</p> <p>Frequency and duration of sessions not reported</p>	<p>(SF-36) survey -ACL insufficiency; using Tegner activity scale (TAS questionnaires -Meniscal surgery -Radiographic osteoarthritis.</p>		<p>-No differences between groups were seen in the number of knees having meniscus surgery ($p = 0.48$) or in a time to event analysis of the proportion of menisci operated on ($p = 0.77$).</p> <p>-No significant difference between mean scores for secondary outcomes for the first five years due to the intervention including pain ($p = 0.73$), function in daily living ($p = 0.38$) and sport ($p = 0.23$) and quality of life ($p = 0.89$).</p> <p>(PEDro score: 6/10; Moderate quality)</p>
5	Hartigan et al. 2009; USA	19 (0)	<p>- 17-50 years old, mean = 29 - Active - Recreational sports person</p>	<p>Control group: (Strengthening group = Str) -Quadriceps strengthening exercises</p> <p>Intervention group: (Perturbation group = Pert) - Specialised neuromuscular training - Quadriceps strengthening exercises</p> <p>Control group – 10 sessions over an average 3.1 weeks</p> <p>Intervention group - 10 sessions over an average 3.7 weeks</p>	<p>- quadriceps strength indexes using a Kin-Com dynamometer. - - knee excursions during the mid-stance phase of gait using a passive, eight camera 3-D motion analysis system (VICON)</p>	<p>-Pre intervention</p> <p>-6 months post ACL reconstruction</p>	<p>- Quadriceps strength indexes before intervention (Pert: 87.2%; Str: 75.8%) improved 6 months after ACL reconstruction in both groups (Pert: 97.1%; Str: 94.4%).</p> <p>- The intervention group had no differences in knee excursions between their limbs 6 months after ACL reconstruction (mean: 3.5 degrees; 95% CI: 8.3 to -1.4; $p = 0.14$), whereas the control group continued to have smaller knee excursions during the mid-stance phase of gait (mean: 7 degrees; 95% CI: 11.6 to 2.5; $p = 0.007$).</p> <p>Strength and knee excursions were more symmetrical 6 months postoperatively in the group that received perturbation training and progressive quadriceps strength training than the group who received strength training alone.</p> <p>(PEDro score: 3/10; Low quality)</p>
6	Shaarani	23	- 18-45 years	Control group:	-Strength	-Baseline	Quadriceps peak torque in the injured

	et al. 2013; Ireland	(3)	old, mean 29 - Active - Recreational sports person	No intervention Intervention group: - Quadriceps muscle strengthening exercises - Balance training - Proprioception training -A 6-week exercise program consisting of 4 exercise periods per week: 2 supervised gym sessions interspersed with 2 supervised home sessions.	assessment; using isokinetic dynamometry. - Function; using the single-legged hop test and Cincinnati Knee Rating System - Changes in quadriceps CSA; using magnetic resonance imaging (MRI) - Detect the myosin heavy chain (MHC) fiber types; using a BioRad DC (detergent compatible) protein assay. - RNA isolation; using TRI reagent (Sigma-Aldrich)	-6 weeks pre-operative -Before ACL reconstruction -12 weeks post-operatively	limb improved with similar gains in CSA compared with baseline ($p = 0.001$). However, this was not significantly increased compared with the control group. Quadriceps and vastus medialis CSA were also larger in the exercise group than in controls ($p = 0.0024$ and $p = 0.015$, respectively). The mean modified Cincinnati score was better in the exercise-injured limb compared with baseline (85 vs 78, $p = 0.004$). Mean single legged-hop test scores were higher preoperatively in the exercise group than the control group (183 vs 156, $p = 0.001$). At 12 weeks postoperatively, the rate of decline in the single-legged hop test was reduced in the exercise group compared with control ($p = 0.001$). (PEDro score: 7/10; High quality)
7	Tagesson et al. 2008; Sweden	49 (7)	- 15-45 years old, mean = 26 - Active - Recreational sports person	- Muscle strengthening - Coordination and Neuromuscular control - Closed kinetic chain exercises (Control group) - Open kinetic chain exercises (Intervention group) - Range of motion (ROM) - Balance and proprioception - Functional specific rehabilitation exercises - Plyometrics The control group	- Swelling; using a tape measure. - Passive ROM for knee extension and flexion; using standard plastic goniometer. - Knee Function and activity level; using Lysholm score and the Knee Injury and Osteoarthritis Outcome Score and Tegner score. - Sagittal static translation and dynamic tibial translation; using CA-4000 electrogoniometer. - Muscle torque for	Baseline -4 Months after rehabilitation	There were no group differences in static or dynamic translation after rehabilitation. The OKC group had significantly higher isokinetic quadriceps strength after rehabilitation (CKC mean = 84, SD = 15; OKC mean = 96, SD = 14; $p = 0.009$). -No differences between the two groups in swelling and passive range of motion before and after the intervention ($p > 0.05$). -The hamstring strength, performance on the 1 repetition maximum squat test, muscle activation, jump performance, and functional outcome were not significantly different between groups ($p > 0.05$). (PEDro score: 6/10; Moderate quality)

				<p>received closed kinetic chain exercises and the intervention group received open kinetic chain exercises.</p> <p>-16 weeks, 3 times per week</p> <p>Duration of sessions not reported.</p>	<p><i>quadriceps and hamstring muscles;</i> using a Biodex machine.</p>		
8	Thomeé et al. 2010; Sweden	40 (16)	<ul style="list-style-type: none"> - 16-55 years old; mean = 30 - Active - Recreational sports person 	<ul style="list-style-type: none"> - Gait re-education - Quadriceps and hamstring muscles strengthening exercises - Range of motion (ROM) -Coordination and balance training - Open and closed kinetic chain exercises - Functional specific rehabilitation exercises <p>Both groups received the same exercises with the intervention group receiving exercises administered by self-efficacy trained physiotherapists.</p> <p>-24 weeks, one hour exercise twice a week</p>	<ul style="list-style-type: none"> -<i>Perceived knee function self-efficacy;</i> using The knee self-efficacy scale (K-SES) -<i>Physical Activity;</i> using Tegner Activity Scale -<i>Knee function, knee-related symptoms and QoL;</i> using The Knee Injury and Osteoarthritis Outcome Score (KOOS) -<i>Locus of control;</i> using The Multidimensional Health Locus Of Control (MHLC). 	<ul style="list-style-type: none"> -Baseline. - 4 months -6 months -12 months 	<p>Current knee-function self-efficacy improved significantly ($p = .05$) in both groups during rehabilitation (Exp Group: mean = 2.9, SD = 2.7, Range: 0.3–9.3; Control Group: mean = 3.0, SD = 2.6, Range: 0.2–8.4)</p> <p>-A significant increase ($p = .05$) was detected for both groups on KOOS SPORT (Exp Group: mean= 50.4, SD:19.8, Range:5–85; Control Group: mean = 59.6, SD = 25.5, Range: 20–95) and KOOS QoL (Exp Group: mean = 50.5, SD =12.6, Range: 25–69; Control Group: mean = 53.7, SD = 13.7, Range: 31–81) between the 4- and 12-month follow-ups</p> <p>-Both groups had a significantly ($p = .05$) lower physical activity level at 12 months than pre-injury. No significant differences were found between groups.</p> <p>PEDro score: 5/10; Moderate quality)</p>

ACL, anterior cruciate ligament; ADLS, Activities of Daily Living Scale; CSA, cross-sectional area; IGF-1, insulin-like growth factor 1; KOOS, Knee Injury and Osteoarthritis Outcome Score; K-SES, knee self-efficacy scale; MAFbx, muscle atrophy f-box; MHC, myosin heavy chain; MHLC, Multidimensional Health Locus Of Control; MRI, magnetic resonance imaging; QoL, Quality of life; RCT, randomized controlled trial; RHCL, reflex hamstring contraction latency; ROM, range of motion; TAS, Tegner activity scale; VIKDE, Vicon Interfaced Knee Displacement Equipment; PEDro, Physiotherapy Evidence Database.

TABLE 2. Summary of methodological quality assessment using the Physiotherapy Evidence Database (PEDro) scale. Scores are out of 10

Study	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Total score (/10)
Beard et al. 1994; UK	Y	Y	N	N	Y	N	Y	Y	Y	Y	Y	7/10 High quality
Fitzgerald et al. 2000; USA	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5/10 Moderate quality
Frobell et al. 2010; Sweden	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7/10 High quality
Frobell et al. 2013; Sweden	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6/10 Moderate quality
Hartigan et al. 2009; USA	Y	Y	N	N	N	N	N	N	N	N	Y	3/10 Low quality
Shaarani et al. 2013; Ireland	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	7/10 High quality
Tagesson	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	6/10

et al. 2008; Sweden												Moderate quality
Thomeé et al. 2010; Sweden	Y	Y	Y	Y	N	N	N	N	N	Y	Y	5/10 Moderate quality

N, no (= 0); Y, yes (= 1)

Items

1. eligibility criteria were specified
2. subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)
3. allocation was concealed
4. the groups were similar at baseline regarding the most important prognostic indicators
5. there was blinding of all subjects
6. there was blinding of all therapists who administered the therapy
7. there was blinding of all assessors who measured at least one key outcome
8. measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"
10. the results of between-group statistical comparisons are reported for at least one key outcome
11. the study provides both point measures and measures of variability for at least one key outcome

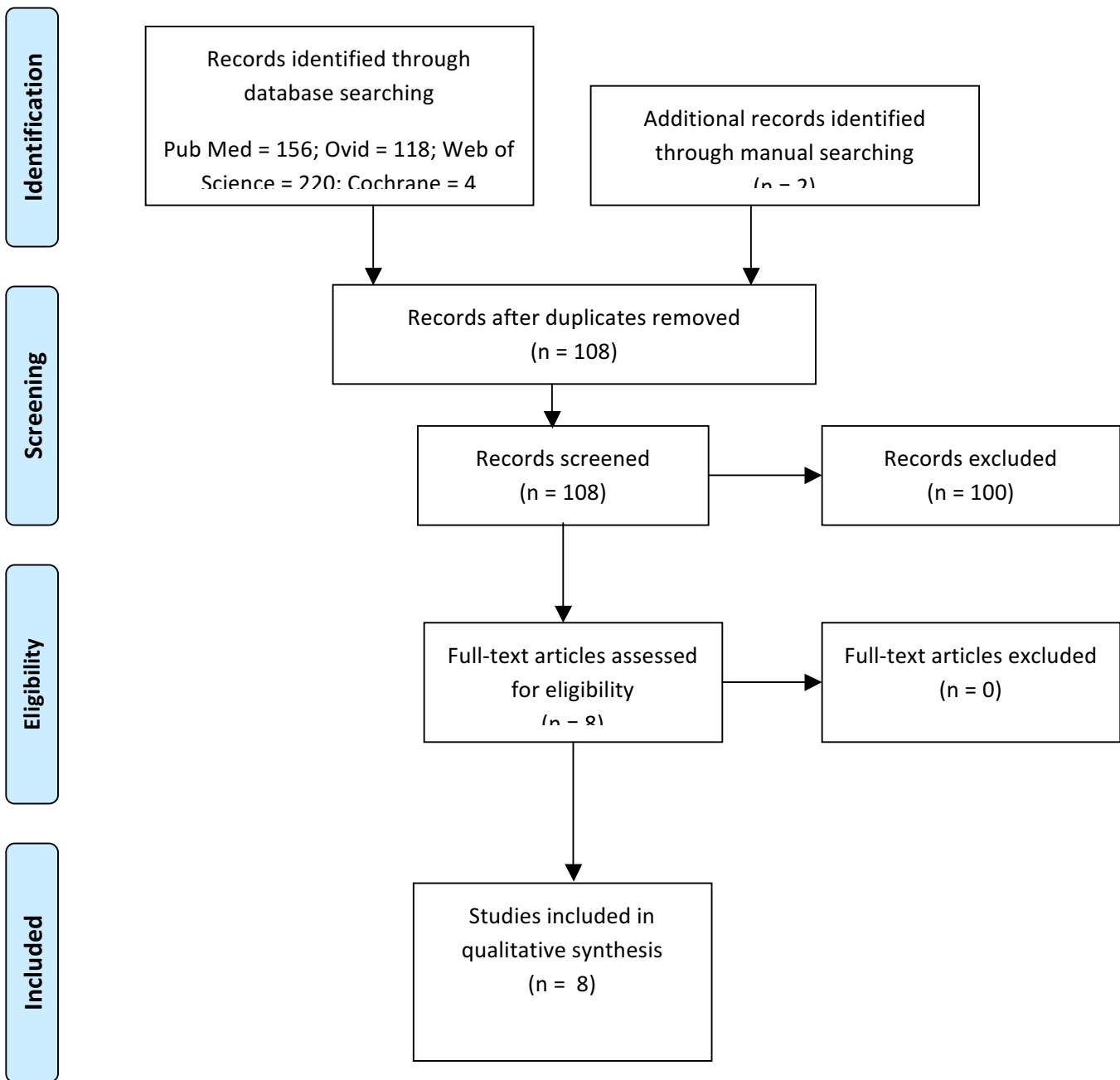


FIGURE 1. PRISMA flow diagram¹⁶ through the different phases of the systematic literature search.