

# Exercise for treating isolated anterior cruciate ligament injuries in adults (Review)

Trees AH, Howe TE, Dixon J, White L



**THE COCHRANE  
COLLABORATION®**

This is a reprint of a Cochrane review, prepared and maintained by The Cochrane Collaboration and published in *The Cochrane Library* 2009, Issue 1

<http://www.thecochranelibrary.com>



## TABLE OF CONTENTS

HEADER . . . . .	1
ABSTRACT . . . . .	1
PLAIN LANGUAGE SUMMARY . . . . .	2
BACKGROUND . . . . .	2
OBJECTIVES . . . . .	3
METHODS . . . . .	3
RESULTS . . . . .	5
DISCUSSION . . . . .	14
AUTHORS' CONCLUSIONS . . . . .	15
ACKNOWLEDGEMENTS . . . . .	15
REFERENCES . . . . .	16
CHARACTERISTICS OF STUDIES . . . . .	19
DATA AND ANALYSES . . . . .	31
Analysis 1.1. Comparison 1 Conservative: supplementary proprioceptive training versus traditional regime, Outcome 1 Lysholm score (0 to 100; 100 being greatest function) at 12 weeks after treatment. . . . .	34
Analysis 2.1. Comparison 2 Conservative: supplementary perturbation training versus standard regime, Outcome 1 Knee Outcome Scores. . . . .	35
Analysis 2.2. Comparison 2 Conservative: supplementary perturbation training versus standard regime, Outcome 2 Return to full activity at 6 month follow up. . . . .	35
Analysis 2.3. Comparison 2 Conservative: supplementary perturbation training versus standard regime, Outcome 3 Isometric MVIC quadriceps (% group mean). . . . .	36
Analysis 2.4. Comparison 2 Conservative: supplementary perturbation training versus standard regime, Outcome 4 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months. . . . .	36
Analysis 3.1. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 1 Lysholm scores (0 to 100; 100 being greatest function). . . . .	37
Analysis 3.2. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 2 Tegner score (% change from pre-injury level of activity) at 6 months after surgery. . . . .	37
Analysis 3.3. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 3 Sickness Impact Profile at 1 year after surgery. . . . .	38
Analysis 3.4. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 4 Muscle strength: torque ratio (% of control limb). . . . .	38
Analysis 3.5. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 5 Knee range of movement (degrees). . . . .	39
Analysis 3.6. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 6 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months after surgery. . . . .	39
Analysis 4.1. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 1 Lysholm score (0 to 100; 100 being greatest function) at 1+ year follow up. . . . .	40
Analysis 4.2. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 2 Tegner score (0 to 10; 10 being greatest level of activity) at 1+ year follow up. . . . .	40
Analysis 4.3. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 3 Hughston Clinic Functional Score (0 to 100; 100 being no disability) at 6 weeks after surgery. . . . .	41
Analysis 4.4. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 4 Patellofemoral pain severe enough to restrict activity at 1 year. . . . .	41
Analysis 4.5. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 5 Knee laxity: anterior sagittal translation (mm). Between limb difference at 1+ year follow up. . . . .	42
Analysis 4.6. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 6 Lachman test: negative at 1 year. . . . .	42
Analysis 5.1. Comparison 5 Reconstruction: closed kinetic chain versus closed and open kinetic chain rehabilitation, Outcome 1 Return to pre-injury level of sport at 31 months after surgery. . . . .	43
Analysis 5.2. Comparison 5 Reconstruction: closed kinetic chain versus closed and open kinetic chain rehabilitation, Outcome 2 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months after surgery. . . . .	43

Analysis 5.3. Comparison 5 Reconstruction: closed kinetic chain versus closed and open kinetic chain rehabilitation, Outcome 3 Isokinetic quadriceps strength (Nm) testing at 6 months after surgery. . . . .	44
Analysis 6.1. Comparison 6 Reconstruction: land based versus water based rehabilitation, Outcome 1 Lysholm score (0 to 100; 100 being greatest function) at 8 weeks after surgery. . . . .	44
Analysis 6.2. Comparison 6 Reconstruction: land based versus water based rehabilitation, Outcome 2 Muscle strength at 8 weeks post surgery (% of contralateral limb). . . . .	45
APPENDICES . . . . .	45
WHAT'S NEW . . . . .	49
HISTORY . . . . .	49
CONTRIBUTIONS OF AUTHORS . . . . .	50
DECLARATIONS OF INTEREST . . . . .	50
SOURCES OF SUPPORT . . . . .	50
INDEX TERMS . . . . .	50

[Intervention Review]

# Exercise for treating isolated anterior cruciate ligament injuries in adults

Amanda H Trees<sup>1</sup>, Tracey E Howe<sup>2</sup>, John Dixon<sup>1</sup>, Lisa White<sup>3</sup>

<sup>1</sup>Centre for Rehabilitation Sciences, University of Teesside, Middlesbrough, UK. <sup>2</sup>HealthQWest, Glasgow Caledonian University, Glasgow, UK. <sup>3</sup>Physiotherapy, South Tees NHS Trust, Middlesbrough, UK

Contact address: Amanda H Trees, Centre for Rehabilitation Sciences, University of Teesside, School of Health and Social Care, Middlesbrough, Tees Valley, TS1 3BA, UK. [a.trees@tees.ac.uk](mailto:a.trees@tees.ac.uk). [amanda.trees@hotmail.co.uk](mailto:amanda.trees@hotmail.co.uk).

**Editorial group:** Cochrane Bone, Joint and Muscle Trauma Group.

**Publication status and date:** Edited (no change to conclusions), published in Issue 1, 2009.

**Review content assessed as up-to-date:** 7 June 2005.

**Citation:** Trees AH, Howe TE, Dixon J, White L. Exercise for treating isolated anterior cruciate ligament injuries in adults. *Cochrane Database of Systematic Reviews* 2005, Issue 4. Art. No.: CD005316. DOI: 10.1002/14651858.CD005316.pub2.

Copyright © 2009 The Cochrane Collaboration. Published by John Wiley & Sons, Ltd.

## ABSTRACT

### Background

The anterior cruciate ligament (ACL) is the most frequently injured ligament of the knee. Injury causes pain, effusion and inflammation leading to the inability to fully activate the thigh muscles. Regaining muscular control is essential if the individual wishes to return to pre-injury level of function and patients will invariably be referred for rehabilitation.

### Objectives

To present the best evidence for effectiveness of exercise used in the rehabilitation of isolated ACL injuries in adults, on return to work and pre-injury levels of activity.

### Search strategy

We searched the Cochrane Bone, Joint and Muscle Trauma Group Specialised Register (Feb 2005), the Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library*, Issue 1, 2005), MEDLINE (1996 to March 2005), EMBASE (1980 to March 2005), other databases and reference lists of articles.

### Selection criteria

Randomised controlled trials and quasi-randomised trials testing exercise programmes designed to rehabilitate adults with isolated ACL injuries. Trials where participants were randomised to receive any combination of the following: no care, usual care, a single-exercise intervention, and multiple-exercise interventions, were included. The primary outcome measures of interest were returning to work and return to pre-injury level of activity post treatment, at six months and one year.

### Data collection and analysis

Two authors independently assessed trial quality and extracted data. Study authors were contacted for additional information. Adverse effects information was collected from the trials.

## Main results

Nine trials involving 391 participants were included. Only two trials, involving 76 participants, reported conservative rehabilitation and seven trials, involving 315 participants, evaluated rehabilitation following ACL reconstruction. Methodological quality scores varied considerably across the trials, with the nature of participant and assessor blinding poorly reported. Trial comparisons fell into six categories. Pooling of data was rarely possible due to lack of appropriate data as well as the wide variety in outcome measures and time points reported. Insufficient evidence was found to support the efficacy of one exercise intervention over another.

## Authors' conclusions

This review has demonstrated an absence of evidence to support one form of exercise intervention against another and the use of supplementary exercises in the management of isolated ACL injuries. Further research in the form of large scale well designed randomised controlled trials with suitable outcome measures and surveillance periods, using standardised reporting should be considered.

## PLAIN LANGUAGE SUMMARY

### Exercise for treating isolated anterior cruciate ligament injuries in adults

The anterior cruciate ligament of the knee controls movement of the lower leg bone (tibia) relative to the thigh bone (femur) and guides knee extension. Injury to this ligament is most common, especially when playing sport, through rapid stopping with a twisting movement. Injuries consist of partial or total tears in the ligament itself or where it attaches to bone. The resulting pain, fluid on the knee and inflammation limit movement and make it difficult to return to normal function and sporting activities. People are treated conservatively, or if the knee has become unstable they may need reconstruction surgery. Rehabilitation programs are an important part of treatment as return to full knee function may limit future degenerative changes in the knee. This review found no strong evidence to support one form of exercise program against another in managing anterior cruciate ligament injuries, looking at return to daily activities, work and sporting activities. Comparisons were of muscle strengthening, in weight bearing and non-weight bearing positions; at home or under supervision; and adding balance and proprioception exercises to a standard rehabilitation program.

This finding was based on nine randomised controlled trials, involving 391 mainly male people aged 15 to 49 years and followed up from 12 weeks to one year. Two trials used conservative treatment and seven trials, involving 315 participants, evaluated rehabilitation following reconstruction surgery. The small numbers of studies, non-standardised exercise programs, methods of looking at their effectiveness and reporting results contributed to the limited conclusions that could be drawn.

## BACKGROUND

The anterior cruciate ligament (ACL) is the most commonly injured ligament of the knee (Ageberg 2002). The incidence of isolated ACL tears is estimated to be 30 per 100,000 of population per year (Miyasaka 1991). The primary role of the ACL is to prevent an anterior translation (forward movement) of the tibia relative to the femur. It also guides the screw-home mechanism associated with knee extension, prevents hyperextension and assists in prevention of varus (bow-leg) and valgus (knock-knee) movement, especially in the extended knee. The most commonly seen mechanism of injury is through rapid deceleration with a twisting movement and hence disruption of the ACL commonly occurs in

athletes. Injuries to the ACL can be defined as complete (total) or incomplete (partial) ruptures and can occur mid-substance or at the origin or insertion.

Following injury to the ACL pain, effusion and inflammation have been shown to lead to muscle inhibition (Snyder-Mackler 1994) and the inability to fully activate the thigh muscles. This, and disuse of the knee musculature, results in muscle atrophy (wasting) and can lead to joint instability. Further immobility is a consequence and a vicious spiral begins. Patients may be treated conservatively (non-operative) and those who demonstrate gross instability of the joint will often undergo reconstructive surgery.

It is proposed by some that regaining muscular control is essential if the individual wishes to return to pre-injury level of function (Henriksson 2001; Mattacola 2002) and patients will invariably be referred for rehabilitation, whether they follow a conservative or reconstructive pathway. Rehabilitation may comprise exercise (defined as “a subset of physical activity, which is volitional, planned, structured, repetitive and aimed at improvement or maintenance of any aspect of fitness or health” (Caspersen 1985)) to improve range of movement, muscle strength, balance and proprioception. Muscle-strengthening exercises can be performed in a variety of ways reflecting the types of muscle action required for normal function. These include isometric (where no movement occurs at the joint), isotonic (where movement occurs at the joint) and isokinetic (where movement occurs at the joint but the speed of movement remains constant). Isotonic and isokinetic contractions can also be performed concentrically (where the muscle shortens, for example using the muscles on the front of the thigh during standing from a seated position), or eccentrically (where the muscle is active but lengthening, for example the muscles on the front of the thigh during sitting from a standing position). Eccentric muscle activity normally occurs to control movement against gravity. Furthermore, exercise for the muscles acting on the knee may be performed as closed kinetic chain activities (weight bearing, where the foot is fixed, for example standing up from a seated position) or open kinetic chain activities (non-weight bearing, where the foot is free to move, for example straightening the knee while seated). Other modalities used during the rehabilitation phase may include cryotherapy (ice), electrotherapy (including muscle stimulation), continuous passive motion, restrictive bracing and complementary therapies such as reflexology or acupuncture.

In a previous comprehensive systematic review (Thomson 2002) the effect of rehabilitation on ACL patients was inconclusive with respect to efficacy of exercise, effectiveness of dosage, setting in which the physiotherapy-led programmes took place and level and type of supervision. Thomson 2002 also limited the trials to physiotherapy-led programmes and did not consider trials when the exercise programmes were prescribed or led by persons other than physiotherapists. That review has now been split and is being updated as a series of separate reviews that includes this current review, and one on exercise for treating isolated meniscal injuries of the knee in adults (Dixon 2005).

This review aimed to examine the effectiveness of exercise employed for the management of isolated ACL injuries in adults, whether treated conservatively or by reconstruction, on return to work and pre-injury levels of activity. For the purposes of this review, we only considered functional exercises such as gait re-education, hydrotherapy, active exercise, balance, proprioception and muscle strengthening. Trials which specifically considered use of restrictive bracing, electrotherapy or electrical stimulation, cryotherapy (ice), continuous passive motion (CPM) and complementary therapies were not considered.

## OBJECTIVES

To present the best evidence for effectiveness of exercise used in the rehabilitation of isolated ACL injuries in adults, whether treated conservatively or by reconstruction, on return to work and pre-injury levels of activity.

The following null hypotheses were formulated.

For isolated ACL injuries treated conservatively:

- there are no differences in outcome between any exercise programme versus none (control) in the rehabilitation of ACL injuries;
- there are no differences in outcome between any exercise programme versus any other exercise programme in the rehabilitation of ACL injuries.

For isolated ACL injuries treated by reconstruction:

- there are no differences in outcome between any exercise programme versus none (control) in the rehabilitation of ACL injuries;
- there are no differences in outcome between any exercise programme versus any other exercise programme in the rehabilitation of ACL injuries.

## METHODS

### Criteria for considering studies for this review

#### Types of studies

Randomised controlled trials and quasi-randomised trials (e.g. randomised by date of birth or hospital record number) testing exercise programmes designed to rehabilitate adults with isolated ACL injuries (conservatively managed or reconstructed).

#### Types of participants

This review included trials with participants described as adults (defined as over the age of sixteen or skeletally mature) with an isolated injury to the ACL. Participant characteristics of interest included age, gender, partial or complete tear, muscle strength and level of physical ability pre-injury.

We excluded trials of interventions targeting individuals that were reported to have damage to structures in addition to the ACL. Trials that focused on participants who had underlying rheumatological, neurological, cardiovascular or congenital conditions affecting the lower limbs were also excluded from the review.

## Types of interventions

Trials where participants were randomised to receive any combination of the following: no care, usual care, a single-exercise intervention, and multiple-exercise interventions. Trials comparing two or more interventions were also included.

For the purpose of this review, exercise was considered if it took one of the following formats.

1. Muscle strengthening
  - a. isometric/isotonic/isokinetic
  - b. concentric/eccentric
  - c. open kinetic chain/closed kinetic chain
2. Joint mobility
  - a. active
  - b. active assisted
  - c. resisted
3. Gait re-education
4. Neuromuscular function/balance and proprioception
5. Land based/water based

The exercise interventions could take place in the home, institutional dwelling, community, gymnasium or clinic setting and could be self-supervised (for example, using exercise sheets/video), individually supervised or as part of a supervised group.

Trials that focused on the following were excluded from the review:

- electrotherapy i.e. ultrasound, Transcutaneous Electrical Nerve Stimulation (TENS), muscle stimulation;
- continuous passive motion and other forms of passive movement;
- restrictive bracing;
- cryotherapy;
- complementary therapies such as reflexology;
- analgesics.

## Types of outcome measures

### Primary outcomes

The primary outcome measures of interest were returning to work and return to pre-injury level of activity post treatment, at six months and one year. To be included, trials must have reported these primary outcome measures. These could have included, but were not restricted to, outcome scales such as the Tegner Activity scale (Tegner 1985), Cincinnati Knee Rating System (Barber-Westin 1999) and Quality of Life Questionnaire for ACL deficiency (Mohtadi 1998).

### Secondary outcomes

Secondary outcome measures could have included, but were not limited to:

- pain (residual pain or pain on movement);

- instability (as tested with arthrometry);
- swelling (for example, patella-tap test);
- range of motion of the knee;
- muscle strength (for example, isokinetic evaluation);
- muscle activation (for example, electromyography analysis (EMG);
  - other complications (e.g. deep vein thrombosis (DVT), infection).

Information was sought on the level of compliance with the intervention, the magnitude and duration of effect, and adverse events associated with the exercise intervention.

## Search methods for identification of studies

We searched the Cochrane Bone, Joint and Muscle Trauma Group Specialised Register (Feb 2005), the Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library*, Issue 1, 2005), MEDLINE (1966 to March 2005), EMBASE (1980 to March 2005), PEDro - The Physiotherapy Evidence Database (<http://www.pedro.fhs.usyd.edu.au/>) (last accessed March 2005), CINAHL (1982 to March 2005), AMED (1985 to March 2005), and reference lists of articles. To identify theses and unpublished trials we contacted institutions and experts in the field. No language restrictions were applied.

In MEDLINE (OVID ONLINE) the first two levels of the optimal trial search strategy (Robinson 2002) were combined with the subject specific search (Appendix 1). Search strategies are also shown for AMED (Appendix 2), CINAHL (Appendix 3), EMBASE (Appendix 4) and *The Cochrane Library* (Appendix 5).

## Data collection and analysis

### Selecting trials for inclusion

At least two authors, and always AT and JD, independently reviewed the title, abstract, and descriptors to identify potentially relevant trials for full review. From the full text, we selected trials that met the selection criteria for inclusion. Disagreement was resolved by consensus or third party adjudication (TH).

### Data collection

Authors (AT and TH) independently extracted data using a customised data extraction tool tested prior to use. Disagreement was resolved by consensus or third party adjudication (JD). We contacted authors of trials if there was incomplete reporting of data.

### Assessment of methodological quality

Two authors (AT and TH) independently assessed the methodological quality of each study by using a modification of the Cochrane Bone, Joint and Muscle Trauma Group quality assessment scheme. The final scoring scheme for 15 aspects of trial quality (Table 1) included items from the Cochrane Bone, Joint and Muscle Trauma Group quality assessment scheme (items denoted by 'M'), items from the Delphi list (Verhagen 1998) (items denoted by 'D') and items from the Maastricht-Amsterdam consensus list for methodological quality assessment (Bellamy 1997) (items denoted by 'MAC'). Any disagreement was resolved by consensus.

### Data synthesis

Trials of ACL injuries treated conservatively were analysed and reported separately from those trials involving reconstruction. Wherever available and appropriate, we presented quantitative data for the outcomes listed in the inclusion criteria in the analysis tables. For each trial, relative risk and 95% confidence intervals were calculated for dichotomous outcomes and mean differences and 95% confidence intervals calculated for continuous outcomes (reporting mean and standard deviation or standard error of the mean).

If appropriate, we intended pooling results of comparable groups of trials using the fixed-effect model and calculating 95% confidence intervals. Heterogeneity between comparable trials would be tested using a standard chi squared test and considered statistically significant at a P value less than 0.1, after due consideration of the value of I squared. Any evidence of heterogeneity would be investigated to determine if there were obvious differences in the trials that were likely causes of the heterogeneity. If we considered that the heterogeneity was likely to have serious effects on the validity of the results then the data would not be combined. Where there was significant heterogeneity we would view the results of the random-effects model and present these when appropriate.

### Sensitivity and subgroup analysis

We intended performing sensitivity analyses to investigate the effects of allocation concealment, methodological quality and intention-to-treat analysis. If the data allowed, we also planned separate outcome analyses to test the following null hypotheses:

- exercise interventions are equally effective in males and females;
- exercise interventions are equally effective irrespective of age;
- effectiveness is not dependant on the setting in which the exercise intervention is delivered;
- effectiveness is not dependant on the level or type of supervision of the exercise intervention;

- effectiveness is not dependant on the number or frequency of exercise sessions i.e. duration of rehabilitation;
- effectiveness is not dependant on the intensity of exercise interventions;
- effectiveness is not dependant on the timing of surgery.

## RESULTS

### Description of studies

See: [Characteristics of included studies](#); [Characteristics of excluded studies](#).

We identified 52 studies up to March 2005, nine of which met the inclusion criteria of the review. We excluded 42 studies, mainly because they did not report the primary outcomes of interest of this review, or they did not fit the criteria for a randomised clinical trial (see 'Characteristics of excluded studies' table for further details). One trial ([Frosch 2001](#)) was placed into 'Studies awaiting assessment' whilst awaiting correspondence from the contact author. A further two trials have been identified since March 2005, and also placed into 'Studies awaiting assessment' ([Beynonn 2005](#); [Shaw 2005](#)). Details of included studies, including interventions and outcomes, are presented in the 'Characteristics of included studies' table.

All of the included nine trials were fully reported in medical journals. Main or sole reports of the included trials were initially located from the trials identified in the original review [Thomson 2002](#) (eight trials), or from electronic databases (one trial). All included trials were published in the English language. The publication dates for the trials included span across eight years, [Beard 1994](#) and [Tovin 1994](#) being the earliest. All except one, ([Hooper 2001](#)) were single centre trials. The trials were conducted in three countries, USA (five trials), UK (three trials) and Sweden (one trial).

For the purpose of this review, the primary outcome measures of interest were returning to work and return to pre-injury level of activity i.e. functional outcomes. The most commonly used primary outcome measures were the Lysholm knee score ([Lysholm 1982](#)) and Tegner activity score ([Tegner 1985](#)). The Lysholm scale is a knee specific outcome, measuring function across eight domains: limp, locking, pain, stair climbing, support, instability, swelling and squatting. An overall score out of 100 is calculated, with a score closer to 100, indicating greater functional ability. The Tegner score is an activity scale rated from zero to ten, with ten indicating participation in elite level sports, and zero indicating inability to participate in activity at any level.

### Exercise as part of conservative management



Only two trials reported conservative rehabilitation (Beard 1994; Fitzgerald 2000). These two trials involved 76 participants, of those, 62 were male and 14 female. The age range of the participants was 16 to 49 years (Beard 1994) and 15 to 57 years (Fitzgerald 2000). In both trials, the number of male participants outnumbered the number of female participants.

Beard 1994 compared the effects of a supplementary proprioceptive training regime in addition to a traditional program versus a traditional program of rehabilitation alone (focussing on increasing muscle strength, predominantly using open kinetic chain exercises). The primary outcome measure of interest used in the trial was the Lysholm score at 12 weeks (immediately post-rehabilitation), and additional measures were evaluation of proprioception and knee laxity. Data was not available for the latter measure.

Fitzgerald 2000 compared the effects of a supplementary perturbation regime in addition to a standard regime versus a standard regime alone (resistive muscle strengthening, cardiovascular endurance training, agility skill training and sport specific training). The primary outcome measures of interest used in the trial were Knee Outcome Scores (Activities of Daily Living and Sports Activities Scales (Irrgang 1998) and Global Rating of Knee Function scale) measured post-treatment and at six months follow up, and a

rating of successful/unsuccessful rehabilitation (return to activity with/without an episode of the knee giving way) measured at one year. Secondary measures were muscle strength and knee laxity post treatment and at six months.

### Exercise following surgical reconstruction

Seven trials evaluated rehabilitation following ACL reconstruction, all trials used the bone-patella-bone method, carried out with arthroscopic assistance. All trials reported the use of autografts (tissue transferred from one site to another in the same individual), with the exception of one trial in which four patients were given allografts (tissue transplanted from one individual to another) (Fischer 1998). The seven trials involved 315 participants, of those, 242 were male and 73 female. Where reported, the age of the participants ranged from 15 to 48 years. In all seven trials, the male participants outnumbered the female participants.

Of the seven included trials, only one reported the mechanisms of injuries (Beard 1998), though several trials reported that their participants were physically active. Fischer 1998 excluded participants who participated in sports at collegiate/professional or elite level. Details of surgery and sports participation for the trials are given in Table 1.

**Table 1. Details of pre-injury sports participation and reconstruction technique**

Study ID	Injury	Reconstruction	Other repair	Sports
Beard 1994	ACL rupture - confirmed by arthroscopy. Acute and Chronic deficient	No	No	No details
Beard 1998	ACL - chronic deficient	Arthroscopically assisted Bone-Patella-Bone middle 1/3 autograft	No	86% Sports injuries
Bynum 1995	ACL - acute and chronic	Arthroscopically assisted Bone-Patella-Bone middle 1/3 autograft	No	Recreational sports participation indicated. Nature of injury not stated
Fischer 1998	ACL - acute and chronic	Arthroscopically assisted Bone-Patella-Bone autograft (4 patients underwent allograft)	No	No collegiate/elite/professional athletes. No other details
Fitzgerald 2000	ACL - within 6 months of injury	No	No	>50 hours of sports per year minimum
Hooper 2001	ACL - chronic	1. Arthroscopically assisted Bone-Patella-Bone middle 1/3 autograft	Partial meniscectomy (n = 10)	No details

**Table 1. Details of pre-injury sports participation and reconstruction technique** (Continued)

		2. Ligamentous augmentation device technique		
Mikkelsen 2000	ACL	Arthroscopically assisted Bone-Patella-Bone middle 1/3 autograft	No	All participants (with exception of 1) were athletes, but it is not stated whether the injury was as a result of the sport
Schenk 1997	ACL	Arthroscopically assisted Bone-Patella-Bone middle 1/3 autograft	No	No details
Tovin 1994	ACL	Arthroscopically assisted Bone-Patella-Bone autograft	No	No details

Three trials (Beard 1998; Fischer 1998; Schenck 1997) compared the effects of rehabilitation at home versus supervised rehabilitation. Participants in each of the trials followed the same rehabilitation programme, with only the level of supervision differing. Primary outcome measures reported were Lysholm score (12 weeks (Fischer 1998), six months (Fischer 1998, Beard 1998) and one year (Schenck 1997), Tegner score at six months (Beard 1998) and Sickness Impact Profile (a generic measure used to evaluate the impact of disease on both physical and emotional functioning) at one year (Schenck 1997). Secondary measures were evaluation of muscle strength, knee range of movement and knee laxity at six months post-reconstruction.

Bynum 1995 and Hooper 2001 compared closed kinetic chain exercise programme versus open kinetic chain programmes. The primary outcome measures of interest used in the trials were Lysholm and Tegner scores measured at one year (Bynum 1995) and Hughston Knee Functional score measured at six weeks (Hooper 2001). Secondary measures reported were severity of patellofemoral pain at one year, knee laxity and Lachman test (clinical test of instability) at one year (Bynum 1995).

Mikkelsen 2000 compared the effect of a closed kinetic chain program versus a combined closed and open kinetic chain program. Both groups followed an identical program for six months but with the open chain group performing additional exercises from week five (post-reconstruction). The primary outcome measure of interest was reported as return to pre-injury level of sport measured at 31 months after surgery. Secondary measures were knee laxity and muscle strength, measured at six months after surgery.

Tovin 1994 compared a land based rehabilitation program with a water based program. Exercises in both programs were identical. The primary outcome measure of interest was the Lysholm score, and the secondary measure was muscle strength. Both outcomes were measured at the end of the eight week program.

### Risk of bias in included studies

Methodological quality scores, on our quality assessment scheme for 15 aspects of trial quality (Table 2), varied considerably across the trials, with Beard 1994 and Beard 1998 being the highest scoring trials, though no trials scored maximally.

**Table 2. Quality assessment items and possible scores**

Items & Scores
M-A (D1b). Was the assigned treatment adequately concealed prior to allocation? 2 = method did not allow disclosure of assignment. 1 = small but possible chance of disclosure of assignment or unclear. 0 = quasi-randomised or open list/tables. Cochrane code: Clearly Yes = A; Not sure = B; Clearly No = C

**Table 2. Quality assessment items and possible scores** (Continued)

M-B (D8). Were the outcomes of patients/participants who withdrew described and included in the analysis (intention to treat)? 2 = withdrawals well described and accounted for in analysis. 1 = withdrawals described and analysis not possible. 0 = no mention, inadequate mention, or obvious differences and no adjustment.
M-C (D4). Were the outcome assessors blinded to treatment status? 2 = effective action taken to blind assessors. 1 = small or moderate chance of unblinding of assessors. 0 = not mentioned or not possible.
M-D (D2). Were the treatment and control group comparable at entry? 2 = good comparability of groups, or confounding adjusted for in analysis. 1 = confounding small; mentioned but not adjusted for. 0 = large potential for confounding, or not discussed.
M-E (D6). Were the participants blind to assignment status after allocation? 2 = effective action taken to blind participants. 1 = small or moderate chance of unblinding of participants. 0 = not possible, or not mentioned (unless double-blind), or possible but not done.
M-F (D5). Were the treatment providers blind to assignment status? 2 = effective action taken to blind treatment providers. 1 = small or moderate chance of unblinding of treatment providers. 0 = not possible, or not mentioned (unless double-blind), or possible but not done.
M-G. Were care programmes, other than the trial options, identical? For example, training programmes, pain relief, advice on activity/mobilisation, follow-up procedures. 2 = care programmes clearly identical. 1 = clear but trivial differences. 0 = not mentioned or clear and important differences in care programmes.
M-H (D3). Were the inclusion and exclusion criteria clearly defined? 2 = clearly defined. 1 = inadequately defined. 0 = not defined.
M-I. Were the interventions clearly defined? 2 = clearly defined interventions are applied with a standardised protocol. 1 = clearly defined interventions are applied but the application protocol is not standardised. 0 = intervention and/or application protocol are poorly or not defined.
M-J. Were the outcome measures used clearly defined? 2 = clearly defined. 1 = inadequately defined. 0 = not defined.
M-K. Were tests used in outcome assessment clinically useful? 2 = optimal.

**Table 2. Quality assessment items and possible scores** (Continued)

1 = adequate. 0 = not defined, not adequate.
M-L. Was the surveillance active, and of clinically appropriate duration (i.e. at least 12 months)? 2 = active surveillance and appropriate duration (12 months follow up or more). 1 = active surveillance, but inadequate duration (6-12 months follow up). 0 = surveillance not active or not defined (0-6 months).
D7. Were point estimates and measures of variability presented for the primary outcome measures? 2 = yes. 1 = point estimates, but no measures of variability presented. 0 = vague descriptions.
MAC-1. Was the compliance rate in each group likely to cause bias? 2 = compliance well described and accounted for in analysis. 1 = compliance well described but differences between groups not accounted for in analysis. 0 = compliance unclear.
MAC-2. Was there a description of adverse effects of the intervention(s)? 2 = well described. 1 = poorly described. 0 = not described.

**Exercise as part of conservative management**

Beard 1994 reported adequate random allocation of participants (computer generated allocation) and treatment allocation was judged as concealed. In Fitzgerald 2000, allocation of participants was generated by computer, but there was insufficient information to judge whether allocation was concealed. Beard 1994 described blinding of both assessors and participants. Both trials scored highly in the description of inclusion/exclusion criteria, definitions of interventions and outcome measures and appropriateness of outcome measures. It was not felt that length of surveillance was adequate for either trial (Beard 1994 12 weeks, and Fitzgerald 2000 five weeks). Neither trial scored highly in the description of compliance or adverse events. Details of the methods of randomisation, extent of assessor and participant blinding, the possibility of intention-to-treat analysis and associated loss to follow up for individual trials are provided in Table 3 and the 'Characteristics of included studies' table.

**Table 3. Methodological quality: conservative management**

Item Code	Beard 1994	Fitzgerald 2000
M-A	2	1

**Table 3. Methodological quality: conservative management** (Continued)

M-B	2	1
M-C	2	0
M-D	2	2
M-E	2	0
M-F	1	0
M-G	2	2
M-H	2	2
M-I	2	2
M-J	2	2
M-K	2	2
M-L	0	0
D-7	2	1
MAC-1	1	0
MAC-2	0	0

### Exercise following surgical reconstruction

Only five of the seven trials reported a method of randomisation, with only [Beard 1998](#) providing adequate details of these methods. Allocation was judged to be concealed in one trial ([Beard 1998](#)), uncertain in the remaining six trials ([Bynum 1995](#); [Fischer 1998](#); [Hooper 2001](#); [Mikkelsen 2000](#); [Schenck 1997](#); [Tovin 1994](#)). With the unavoidably difficult task of blinding the treatment providers to group allocation, it would seem essential to blind assessors. Only two trials ([Beard 1998](#); [Bynum 1995](#)) stated the assessors were fully blinded, though one trial ([Schenck 1997](#)) reported the use of an independent assessor. With the exception of [Beard 1998](#), there was insufficient information to confirm that intention-to-treat analysis had been carried out.

All trials provided descriptions of the inclusion and exclusion criteria, and definitions of interventions and outcome measures. Adequate surveillance ([Table 2](#) 'Quality assessment items and possible scores' item M-L) was only carried out in two trials; [Bynum 1995](#) average of 19 months and [Mikkelsen 2000](#) average of 31 months for return to pre-injury level of sport. Reporting of adverse events and compliance was poor for all seven trials. Details of the methods of randomisation, extent of assessor and participant blinding, the possibility of intention-to-treat analysis and associated loss to follow up for individual trials are provided in [Table 4](#) and the 'Characteristics of included studies' table.

**Table 4. Methodological quality: post reconstruction management**

Item code	Beard 1998	Bynum 1995	Fischer 1998	Hooper 2001	Mikkelsen 2000	Schenk 1997	Tovin 1994
M-A	2	1	1	1	1	1	1
M-B	2	0	0	0	0	0	0
M-C	2	2	0	0	1	1	1
M-D	2	2	0	2	2	0	2
M-E	2	0	0	0	0	0	0
M-F	0	0	0	0	0	0	0
M-G	2	2	2	0	2	2	2
M-H	1	1	2	2	2	1	1
M-I	2	2	2	2	2	1	2
M-J	2	2	2	2	2	1	2
M-K	2	2	1	1	1	1	1

**Table 4. Methodological quality: post reconstruction management** (Continued)

M-L	1	2	1	0	2	1	0
D-7	2	1	0	2	1	0	2
MAC-1	1	0	0	0	0	0	0
MAC-2	0	0	0	0	0	0	0

### Effects of interventions

No trials were included that reported the effect of exercise versus no exercise.

#### Exercise as part of conservative management

##### Supplementary proprioceptive training versus traditional regime (Comparison 01)

In Beard 1994 (50 participants) there was no significant difference at twelve weeks post-treatment, between the traditional regime with supplementary proprioceptive training and a traditional regime alone in improving functional status, as measured by the Lysholm score (WMD 7.00, 95% confidence interval (CI) -4.01 to 18.01) (see Graph 01.01).

##### Supplementary perturbation training versus standard regime (Comparison 02)

In a small study by Fitzgerald 2000 (26 participants), there was no significant difference post-treatment or at the six month follow-up assessment in Knee Outcome Scores (Activities of Daily Living, Sports Activity scores, Global Rating of Knee Function) between the standard regime supplemented by perturbation training versus the standard regime alone (see Graph 02.01). However, return to full activity at six months was more common for the group receiving supplementary perturbation training (RR 1.83, 95% CI 1.06 to 3.18) (see Graph 02.02), although the definition of “successful outcome” for return to full activity was not clear and the methods for acquiring this data not described in the text. There was no difference between the groups for other secondary outcome measures: isometric quadriceps strength measured post-treatment and at six months and knee laxity measured post-treatment (see Graphs 02.03 and 02.04).

### Exercise following surgical reconstruction

#### Home based versus supervised rehabilitation (Comparison 03)

We identified one outcome measure (Lysholm score) and time point (six months) that was addressed by more than one trial and allowed pooling of data (Beard 1998; Fischer 1998). These trials involving a total of 80 participants compared home based versus supervised rehabilitation. There was no evidence of a difference between the two groups (WMD 1.46, 95% CI -3.19 to 6.10) (see Graph 03.01). Additional non-pooled data did not demonstrate a difference in Lysholm score at twelve weeks (Fischer 1998) or in Tegner score (per cent change) at six months (Beard 1998).

There was no difference between the groups for other secondary outcome measures: muscle strength (torque ratio) measured at three and six months (Beard 1998), knee laxity measured at six months (Beard 1998) or knee range of movement (ROM) measured at 6 and 12 weeks (Fischer 1998). Knee ROM at 18 and 24 weeks showed a difference between the groups (18 weeks: WMD -6.00, 95% CI -11.76 to -0.24 and 24 weeks: WMD -8.00, 95% CI -12.92 to -3.08) (see Graph 03.05), favouring home based exercise (Fischer 1998). It is not known at what point in the range of movement these improvements were deemed to have been made i.e. resolving lack of extension or improving flexion. The average differences between the groups of six to eight degrees may not be a clinically important change as the precision of measuring joint range with goniometers and visual estimation is limited to similar values (Watkins 1991). Furthermore, the data used for the purposes of this review were taken from visual estimates of figures in the original paper. Although the outcome measures reported by Fischer 1998 were appropriate, the overall methodological reporting of this trial was poor.

#### Closed kinetic chain versus open kinetic chain rehabilitation (Comparison 04)



Trials investigating closed kinetic chain versus open kinetic chain rehabilitation did not demonstrate any differences between the groups in knee function: Hughston Clinic Functional Score at six weeks post surgery (Hooper 2001) (WMD 0.00, 95% CI -9.34 to 9.34) (see Graph 04.03) and patellofemoral pain severe enough to restrict activity at one year (Bynum 1995) (RR 1.34, 95% CI 0.59 to 3.07) (see Graph 04.04). There was no difference between the groups for the secondary outcome measure, negative Lachman test measured at one year (Bynum 1995) (RR 0.93, 95% CI 0.80 to 1.09) (see Graph 04.06). However Bynum 1995 did not report the levels at which participants were restricted from activity, nor the degree of patellofemoral pain causing restriction to activity.

#### **Closed kinetic chain versus closed and open kinetic chain rehabilitation (Comparison 05)**

In a trial of 44 participants, return to pre-injury level of sport by 31 months after surgery was statistically significantly more common in the closed and open kinetic chain rehabilitation program compared to the closed chain only program (Mikkelsen 2000) (RR 0.42, 95% CI 0.18 to 0.98) (see Graph 05.01). There was no difference between the groups for the secondary outcome measures: knee laxity and isokinetic quadriceps strength measured at six months post-surgery (see Graphs 05.02 and 05.03).

#### **Land based versus water based rehabilitation (Comparison 06)**

In a small study by Tovin 1994 (19 participants) comparing land and water based rehabilitation, a higher Lysholm score, measured at eight weeks, was observed in the water based group (WMD 9.80, 95% CI 1.29 to 18.31) (see Graph 06.01). There was no difference between groups in muscle strength measured at eight weeks, with the exception of peak isokinetic torque 90°/second - flexion which favoured land based rehabilitation (WMD -14.70, 95% CI -25.89 to -3.51) (see Graph 06.02).

#### **Subgroup analysis**

The effect of the setting and level of supervision on the effectiveness of exercise programmes were considered in comparison 03 (home based versus supervised rehabilitation) and comparison 06 (land versus water based rehabilitation) and reported above. However, due to the limitations of the data available, we were unable to perform separate subgroup analyses to test the following null hypotheses:

- exercise interventions are equally effective in males and females;
- exercise interventions are equally effective irrespective of age;
- effectiveness is not dependant on the number or frequency of exercise sessions i.e. duration of rehabilitation;

- effectiveness is not dependant on the intensity of exercise interventions;
- effectiveness is not dependant on the timing of surgery.

## **DISCUSSION**

This review aimed to examine the effectiveness of exercise employed for the management of isolated ACL injuries in adults, whether treated conservatively or by reconstruction, on return to work and pre-injury levels of activity. For the purposes of this review, we only considered exercises such as gait re-education, hydrotherapy, active exercise, balance, proprioception and muscle strengthening. Trials which specifically considered use of restrictive bracing, electrotherapy or electrical stimulation, cryotherapy (ice), continuous passive motion (CPM) and complementary therapies were not considered.

In all, the search to March 2005 resulted in the identification of 52 trials. Nine trials, involving 391 participants (304 male and 87 female) met the inclusion criteria of the review. Only two trials, involving 76 participants, reported conservative (non-operative) rehabilitation and seven trials, involving 315 participants, evaluated rehabilitation following ACL reconstruction.

Methodological quality scores varied considerably across the trials, with the participant and assessor blinding poorly reported. Sample sizes of the included trials ranged from 20 to 97 participants raising questions as to the power of individual trials. Adequate surveillance (at least one year) was only observed in two trials, Bynum 1995 average of 19 months (Lysholm score) and Mikkelsen 2000 average of 31 months (return to pre-injury levels of sport). The nature of the intervention - exercise - makes it virtually impossible for trials to be blinded to care providers and participants, although blinding of assessors would be possible.

Most comparisons were of usual care only versus usual care with supplementary exercise. No trials reported the use of a control group (participants receiving no treatment). However, the nature of injury to the ACL is typically suggestive of individuals who participate in sporting activities, and who may be reluctant to forgo any form of rehabilitation with the perception that this may further delay a return to their normal activities.

For the purposes of this review, the primary outcome measures of interest were; returning to work and return to pre-injury level of activity post treatment, at six months and one year. The trials included in this review reported on these using a variety of measures including the Tegner Activity scale (Tegner 1985), Lysholm score, Knee Outcome Score Activities of Daily Living (Irrgang 1998) and return to pre-injury level of activity. Though appropriate outcome measures, there was inconsistency between trials on the surveillance periods, ranging from five weeks (Fitzgerald 2000) to 31 months post-treatment (Mikkelsen 2000). It is reported that

patients with ACL reconstruction may not regain normal muscle strength at the knee until 10 to 22 months following surgery during walking and even longer during running (DeVita 1998), and similarly restoration of proprioceptive function in the knee may take up to 18 months (Iwasa 2000). Therefore the time points of six months and one year selected for this review maybe insufficient despite the introduction of accelerated programmes of four to six months duration.

Secondary outcome measures reported included; knee range of movement, muscle strength (isometric and various speeds of isokinetic), knee laxity, proprioceptive ability and gait analysis.

The most important feared consequence of dynamic exercise or testing at high intensity is damage to a reconstructed or partially ruptured anterior cruciate ligament or further damage to the structures around the knee joint. This factor places a limitation on the aggressiveness of the clinical outcome measures to assess success efficacy of interventions. For example, using Noyes Hop Test (Noyes 1991) as a measure in the early stages post-ACL reconstruction or acute stages of a partial or complete rupture treated conservatively would be deemed inappropriate, though clinically it would be useful in the later stages of rehabilitation and prior to returning to sport.

The International Classification of Functioning, Disability and Health (ICF) was endorsed by the World Health Organization in 2001 (WHO 2001) as a conceptual framework for the description of health and health related states. The multi-dimensional concepts relate to disability and functioning and the consequences of health conditions. The ICF assists in scientific research by providing a framework or structure for research and for making results of research comparable.

The wide variety of outcome measures used in trials included in this review supports the need for a general agreement about outcome measures used in trials of exercise based interventions. International consensus on a core set of outcome measures and surveillance periods to determine the effect of exercise therapy, for example, knee outcome scales, muscle strength, joint mobility and knee laxity, should be considered.

In this review comparisons fell into six categories. Pooling of data was impeded by lack of appropriate data as well as the wide variety of outcome measures and surveillance periods. This was compounded further by differences in test protocols and test equipment in measuring knee outcome scales, muscle strength, range of movement and joint laxity. The Lysholm score was the only measure applied in more than one trial that compared the same exercise interventions. Due to these and other methodological and reporting factors the authors of this review conclude that there is

insufficient evidence to support the efficacy of one exercise intervention over another in the conservative or post-reconstruction rehabilitation of adults with isolated anterior cruciate ligament injuries on return to work or pre-injury levels of activity.

## AUTHORS' CONCLUSIONS

### Implications for practice

Conventionally, clinicians treating ACL injuries aim to restore function and assist patients in a return to pre-injury levels of activity, by 'prescribing' an exercise program to increase joint mobility, muscle strength, proprioceptive awareness and general fitness and many such interventions have been reported.

Given that joint dysfunction has a tendency to lead to the development of degenerative joint disease, a priority for clinicians should be to encourage full restoration of function using an accepted efficacious programme of rehabilitation. This review has demonstrated an absence of evidence to support one form of exercise intervention against another in the management of isolated ACL injuries. Results of the long term effect of exercise are not available due to the inadequate length of surveillance of trials.

### Implications for research

This review has demonstrated an absence of evidence to support one form of exercise intervention against another in the management of isolated ACL injuries. Further research in the form of large scale well designed randomised controlled trials with suitable outcome measures and surveillance periods, using standardised reporting should be considered. International consensus on a core set of outcome measures and surveillance periods to determine the effect of exercise therapy for example; knee outcome scales, muscle strength, joint mobility and knee laxity should be considered.

## ACKNOWLEDGEMENTS

We would like to thank the following for their helpful editorial comments on the protocol and review: A/Prof Peter Herbison, Prof Rajan Madhok, Dr Janet Wale, Prof Sallie Lamb and Prof David Baxter. We would like to thank Lesley Gillespie for her help with developing the search strategy and Lindsay Thomson, Helen Handoll, Aileen Cunningham and Trenea Shaw for their work on the previous review (Thomson 2002). We would like to thank Lesley Gillespie, Jane Dennis and Anette Bluemle for their invaluable help with the translations and Jayne Elms for her help with management of the review.

## REFERENCES

### References to studies included in this review

#### Beard 1994 *{published data only}*

Beard D, Dodd C, Trundle H, Simpson A. Rehabilitation of anterior cruciate ligament deficiency: a randomised clinical trial [abstract 124]. 6th Congress of the European Society of Sports Traumatology, Knee Surgery and Arthroscopy (ESSKA); 1994 Apr 18 -22; Berlin. 1994:89-90.

\* Beard DJ, Dodd CA, Trundle HR, Simpson AH. Proprioception enhancement for anterior cruciate ligament deficiency. A prospective randomised trial of two physiotherapy regimes. *Journal of Bone and Joint Surgery - British Volume* 1994;**76**(4):654-9.

#### Beard 1998 *{published data only}*

Beard DJ, Dodd CA. Home or supervised rehabilitation following anterior cruciate ligament reconstruction: a randomized controlled trial. *Journal of Orthopaedic and Sports Physical Therapy* 1998;**27**(2):134-43.

#### Bynum 1995 *{published data only}*

\* Bynum EB, Barrack RL, Alexander AH. Open versus closed chain kinetic exercises after anterior cruciate ligament reconstruction. A prospective randomized study. *American Journal of Sports Medicine* 1995;**23**(4):401-6.

Kirkley A. Closed kinetic chain exercises after anterior cruciate ligament reconstruction [abstract]. *Clinical Journal of Sport Medicine* 1996;**6**(1):66.

Rennison M. Open versus closed chain kinetic exercises after anterior cruciate ligament reconstruction. A prospective randomized study [letter; comment]. *American Journal of Sports Medicine* 1996;**24**(1):125.

#### Fischer 1998 *{published data only}*

Fischer DA. Home-based rehabilitation after ACL reconstruction [abstract]. *Orthopaedic Transactions* 1996;**20**(2):337.

Fischer DA, Samani JE, Tewes DP, Boyd JL, Smith JP. Home-based rehabilitation for anterior cruciate ligament reconstruction [abstract]. *Orthopaedic Transactions* 1997;**21**(1):196.

\* Fischer DA, Tewes DP, Boyd JL, Smith JP, Quick DC. Home based rehabilitation for anterior cruciate ligament reconstruction. *Clinical Orthopaedics and Related Research* 1998;**(347)**:194-9.

#### Fitzgerald 2000 *{published and unpublished data}*

Fitzgerald GK, Axe MJ, Snyder-Mackler L. The efficacy of perturbation training in nonoperative anterior cruciate ligament rehabilitation programs for physical active individuals. *Physical Therapy* 2000;**80**(2):128-40.

#### Hooper 2001 *{published data only}*

Hooper DM, Morrissey MC, Dreschler W, Morrissey D, King J. Open and closed kinetic chain exercises in the early period after anterior cruciate ligament reconstruction: Improvements in level walking, stair ascent, and stair descent. *American Journal of Sports Medicine* 2001;**29**(2):167-74.

#### Mikkelsen 2000 *{published data only}*

Mikkelsen C, Werner S, Eriksson E. Closed kinetic chain alone compared to 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**(6):337-42.

#### Schenck 1997 *{published data only}*

Schenck RC, Blaschak MJ, Lance E. A prospective outcome study following ACL reconstruction [abstract]. *Orthopaedic Transactions* 1996;**20**(4):957-8.

Schenck RC, Lance ED, Holmes CF. A prospective outcome study of home rehabilitation programs following ACL reconstruction [abstract]. *Orthopaedic Transactions* 1996;**20**(4):911-2.

\* Schenck RC Jr, Blaschak MJ, Lance ED, Turturro TC, Holmes CF. A prospective outcome study of rehabilitation programs and anterior cruciate ligament reconstruction. *Arthroscopy* 1997;**13**(3):285-90.

Schenck RJ. The advantages of home rehabilitation following ACL reconstruction [abstract]. *Orthopaedic Transactions* 1995;**19**(3):824.

#### Tovin 1994 *{published data only}*

Tovin BJ, Wolf SL, Greenfield BH, Crouse J, Woodfin BA.

Comparison of the effects of exercise in water and on land on the rehabilitation of patients with intra-articular anterior cruciate ligament reconstructions. *Physical Therapy* 1994;**74**(8):710-9.

### References to studies excluded from this review

#### Blanpied 2000 *{published data only}*

Blanpied P, Carroll R, Douglas T, Lyons M, Macalisang R, Pires L. Effectiveness of lateral slide exercise in an anterior cruciate ligament reconstruction rehabilitation home exercise program. *Journal of Orthopaedic and Sports Physical Therapy* 2000;**30**(10):602-8; discussion 609-11.

#### Brandsson 2001 *{published data only}*

Brandsson S, Faxén E, Kartus J, Eriksson BI, Karlsson J. Is a knee brace advantageous after anterior cruciate ligament surgery? A prospective, randomized study with a two-year follow-up. *Scandinavian Journal of Medicine and Science in Sports* 2001;**11**(2):110-4.

#### Decker 2004 *{published data only}*

Decker MJ, Torry MR, Noonan TJ, Sterett WI, Steadman JR. Gait retraining after anterior cruciate ligament reconstruction. *Archives of Physical Medicine and Rehabilitation* 2004;**85**(5):848-56.

#### Donatelli 1996 *{published data only}*

Donatelli R, Cole SP, Greenfield B, Wodden M, Wilkes JS, Lackey C. Open and closed kinetic chain strength training versus functional exercises to improve performance in patients with ACL reconstructed knees: a prospective study. *Isokinetics and Exercise Science* 1996;**6**(1):7-13.

#### Draper 1990 *{published data only}*

Draper V. Electromyographic biofeedback and recovery of quadriceps femoris muscle function following anterior cruciate ligament reconstruction. *Physical Therapy* 1990;**70**(1):11-7.

#### Ekstrand 1990 *{published data only}*

Ekstrand J. Six versus eight months of rehabilitation after reconstruction of the anterior cruciate ligament: a prospective randomized study on soccer players. *Science and Football* 1990;**3**:31-6.

- Frobese 1993** {published data only}  
Frobese I, Verdonck A, Duesberg F, Mucha C. Effects of different stress intensities in postoperative training on performance deficits of the quadriceps muscle of the thigh [Auswirkungen unterschiedlicher Belastungsintensitäten eines post-operativen stationären Aufbautrainings auf Leistungsdefizite des M.quadriceps femoris]. *Zeitschrift für Orthopädie und Ihre Grenzgebiete* 1993;**131**(2):164–7.
- Hehl 1995** {published data only}  
Hehl G, Hoellen I, Wissmeyer T, Ziegler U. Isokinetic muscle training with high motion velocities in rehabilitation after operative treatment of acute ruptures of the anterior cruciate ligament [Isokinetisches Muskeltraining mit hohen Bewegungsgeschwindigkeiten in der Rehabilitation nach operativer Verorgung frischer vorderer Kreuzbandrupturen]. *Zeitschrift für Orthopädie und Ihre Grenzgebiete* 1995;**133**(4):306–10.
- Hehl 2003** {published data only}  
Hehl G, Müller EM, Bair K, Pokar S, Beck A. Efficacy of stairclimber for closed kinetic chain muscle strengthening after anterior cruciate ligament reconstruction [Wirksamkeit des Stepertrainings als Muskelaufbautraining im geschlossenen System nach operativ versorgter vorderer Kreuzbandruptur]. *Sportverletzung Sportschaden* 2003;**17**:171–5.
- Hooper 2002** {published data only}  
Hooper DM, Hill H, Dreschler WI, Morrissey MC. Range of motion specificity resulting from closed and open kinetic chain resistance training after anterior cruciate ligament reconstruction. *Journal of Strength and Conditioning Research* 2002;**16**(3):409–15.
- Knaepler 1994** {published data only}  
Knaepler H, Schenk C. The new “Marburg rehabilitation concept”. “On the status of exercise equipment within the scope of rehabilitation of patients after surgery of the anterior cruciate ligament” [Das neue “Marburger Rehabilitationskonzept”. “Über den Stellenwert von Übungsgeräten im Rahmen der Rehabilitation von Patienten nach Operationen am vorderen Kreuzband”]. *Aktuelle Traumatologie* 1994;**24**(1):17–23. [MEDLINE: 8165955]
- McClintock 1995** {published data only}  
McClintock JH, Kirkley A, Fowler PJ. Prospective randomized clinical trial of standard physiotherapy versus aquatic therapy for early rehabilitation of the ACL reconstructed knee [abstract]. *Journal of Bone and Joint Surgery - British Volume* 1995;**77** Suppl 3: 313–4.
- Meyers 2002** {published data only}  
Meyers MC, Sterling JC, Marley RR. Efficacy of stairclimber versus cycle ergometry in postoperative anterior cruciate ligament rehabilitation. *Clinical Journal of Sports Medicine* 2002;**12**(2): 85–94.
- Moller 2001** {published data only}  
Moller E, Forssblad M, Hansson L, Wange P, Weidenhielm L. Bracing versus nonbracing in rehabilitation after anterior cruciate ligament reconstruction: a randomized prospective study with 2-year follow-up. *Knee Surgery, Sports Traumatology, Arthroscopy* 2001;**9**:102–8.
- Morrissey 2000** {published data only}  
Morrissey MC, Hudson ZL, Dreschler WI, Coutts FJ, Knight PR, King JB. Effects of open versus closed kinetic chain training on knee laxity in the early period after anterior cruciate ligament reconstruction. *Knee Surgery, Sports Traumatology, Arthroscopy* 2000;**8**(6):343–8.
- Morrissey 2002** {published data only}  
Morrissey MC, Dreschler WI, Morrissey D, Knight PR, Armstrong PW, McAuliffe TB. Effects of distally fixated versus nondistally fixated leg extensor resistance training on knee pain in the early period after anterior cruciate ligament reconstruction. *Physical Therapy* 2002;**82**(1):35–43.
- Oberg 1991** {published data only}  
Oberg B. Strength training for anterior cruciate ligament injuries: a randomized study of different training programmes [abstract]. Proceedings of the 11th International Congress of World Confederation for Physical Therapy; 1991 July; London (UK). 1991:1434–5.
- Ohta 2003** {published data only}  
Ohta H, Kurosawa H, Ikeda H, Iwase Y, Satou N, Nakamura S. Low-load resistance muscular training with moderate restriction of blood flow after anterior cruciate ligament reconstruction. *Acta Orthopaedica Scandinavica* 2003;**74**(1):62–8.
- Risberg 1999** {published data only}  
Risberg MA, Holm I, Steen H, Eriksson J, Ekeland A. The effect of knee bracing after anterior cruciate ligament reconstruction: a prospective, randomized study with two years’ follow-up. *American Journal of Sports Medicine* 1999;**27**(1):76–83.
- Thomeé 1987** {published data only}  
Thomeé R, Renström P, Grimby G, Peterson L. Slow or fast isokinetic training after knee ligament surgery. *Journal of Orthopaedic and Sports Physical Therapy* 1987;**8**(10):475–9.
- Timm 1997** {published data only}  
Snyder-Mackler L. Follow-up to the clinical and cost effectiveness of two different programs for rehabilitation following ACL reconstruction [comment]. *Journal of Orthopaedic and Sports Physical Therapy* 1997;**26**(1):39; author reply 40–6.  
\* Timm KE. The clinical and cost-effectiveness of two different programs for rehabilitation following ACL reconstruction. *Journal of Orthopaedic and Sports Physical Therapy* 1997;**25**(1):43–8.
- Tsaklis 2002** {published data only}  
Tsaklis P, Abatzides G. ACL rehabilitation program using a combined isokinetic and isotonic strengthening protocol. *Isokinetics and Exercise Science* 2002;**10**(4):211–9.
- Zatterstrom 1998** {published data only}  
Friden T, Zatterstrom R, Lindstrand A, Moritz U. Early training after acute anterior cruciate ligament rupture [abstract]. *Acta Orthopaedica Scandinavica. Supplementum* 1989;**231**:29.  
\* Zatterstrom R, Friden T, Lindstrand A, Moritz U. Early rehabilitation of acute anterior cruciate ligament injury - a randomized clinical trial. *Scandinavian Journal of Medicine and Science in Sports* 1998;**8**(3):154–9.  
Zatterstrom R, Friden T, Lindstrand A, Moritz U. Rehabilitation following acute anterior cruciate ligament injuries—a 12-month follow-up of a randomized clinical trial. *Scandinavian Journal of Medicine and Science in Sports* 2000;**10**(3):156–63.

## References to studies awaiting assessment

**Beynonn 2005** *{published data only}*

Beynonn BD, Uh BS, Johnson RJ, Abate JA, Nichols CE, Fleming BC, et al. Rehabilitation after anterior cruciate ligament reconstruction. A prospective, randomized, double-blind comparison of programs administered over 2 different time intervals. *American Journal of Sports Medicine* 2005;**33**(3):347–59.

**Frosch 2001** *{published data only}*

Frosch KH, Habermann F, Fuchs M, Michel A, Junge R, Schmidtman U, et al. Is prolonged ambulatory physical therapy after anterior cruciate ligament-plasty indicated? Comparison of costs and benefits [Ist die erweiterte ambulante Physiotherapie (EAP) nach vorderer Kreuzbandersatzplastik indiziert]. *Unfallchirurg* 2001;**104**:513–8.

**Shaw 2005** *{published data only}*

Shaw T, Williams MT, Chipchase LS. Do early quadriceps exercises affect the outcome of ACL reconstruction? A randomised controlled trial. *Australian Journal of Physiotherapy* 2005;**51**(1):9–17.

**Additional references****Ageberg 2002**

Ageberg E. Consequences of a ligament injury on neuromuscular function and relevance to rehabilitation - using the anterior cruciate ligament-injured knee as model. *Journal of Electromyography and Kinesiology* 2002;**12**(3):205–12.

**Barber-Westin 1999**

Barber-Westin SD, Noyes FR, McCloskey JW. Rigorous statistical reliability, validity, and responsiveness testing of the Cincinnati knee rating system in 350 subjects with uninjured, injured, or anterior cruciate ligament-reconstructed knees. *American Journal of Sports Medicine* 1999;**27**(4):402–16.

**Bellamy 1997**

Bellamy N, Kirwan J, Boers M, Brooks P, Strand V, Tugwell P, et al. Recommendations for a core set of outcome measures for future phase III clinical trials in knee, hip, and hand osteoarthritis. Consensus development at OMERACT III. *Journal of Rheumatology* 1997;**24**(4):799–802.

**Caspersen 1985**

Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Reports* 1985;**100**(2):126–31.

**DeVita 1998**

DeVita P, Hortobagyi T, Barrier J. Gait biomechanics are not normal after anterior cruciate ligament reconstruction and accelerated rehabilitation. *Medicine and Science in Sports and Exercise* 1998;**30**(10):1481–8.

**Dixon 2005**

Dixon J, Trees AH, Howe TE. Exercise for treating isolated meniscal injuries of the knee in adults. *Cochrane Database of Systematic Reviews* 2005, Issue 3. [Art. No.: CD005466. DOI: 10.1002/14651858.CD005466.pub2]

**Henriksson 2001**

Henriksson M, Ledin T, Good L. Postural control after anterior cruciate ligament reconstruction and functional rehabilitation. *American Journal of Sports Medicine* 2001;**29**(3):359–66.

**Irrgang 1998**

Irrgang JJ, Snyder-Mackler L, Wainner RS, Fu FH, Harner CD. Development of a patient-reported measure of function of the knee. *Journal of Bone and Joint Surgery - American Volume* 1998;**80**(8):1132–45.

**Iwasa 2000**

Iwasa J, Ochi M, Adachi N, Tobita M, Katsube K, Uchio Y. Proprioceptive improvement in knees with anterior cruciate ligament reconstruction. *Clinical Orthopaedics and Related Research* 2000;**(318)**:168–76.

**Lysholm 1982**

Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with a special emphasis on use of a scoring scale. *American Journal of Sports Medicine* 1982;**10**(3):150–4.

**Mattacola 2002**

Mattacola CG, Perrin DH, Gansneder BM, Gieck JH, Saliba EN, McCue FC. Strength, functional outcome, and postural stability after anterior cruciate ligament reconstruction. *Journal of Athletic Training* 2002;**37**(3):262–8.

**Miyasaka 1991**

Miyasaka KC, Daniel D, Stone ML, Hirshman P. The incidence of knee ligament injuries in the general population. *American Journal of Knee Surgery* 1991;**4**:3–7.

**Mohtadi 1998**

Mohtadi N. Development and validation of the quality of life outcome measure (questionnaire) for chronic anterior cruciate ligament deficiency. *American Journal of Sports Medicine* 1998;**26**(3):350–9.

**Noyes 1991**

Noyes FR, Barber SD, Mangine RE. Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *American Journal of Sports Medicine* 1991;**19**(5):513–8.

**Robinson 2002**

Robinson KA, Dickersin K. Development of a highly sensitive search strategy for the retrieval of reports of controlled trials using PubMed. *International Journal of Epidemiology* 2002;**31**(1):150–3.

**Snyder-Mackler 1994**

Snyder-Mackler L, De Luca PF, Williams PR, Eastlack ME, Bartolozzi AR 3rd. Reflex inhibition of the quadriceps femoris muscle after injury or reconstruction of the anterior cruciate ligament. *Journal of Bone and Joint Surgery - American Volume* 1994;**76**(4):555–60.

**Tegner 1985**

Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clinical Orthopaedics and Related Research* 1985;**(198)**:43–9.

**Thomson 2002**

Thomson LC, Handoll HH, Cunningham A, Shaw PC. Physiotherapist-led programmes and interventions for rehabilitation of anterior cruciate ligament, medial collateral ligament and meniscal injuries of the knee in adults (Withdrawn Cochrane Review). *Cochrane Database of Systematic Reviews* 2002, Issue 2.

**Verhagen 1998**

Verhagen AP, de Vet HC, di Bie RA, Kessels AG, Boers M, Bouter LM, et al. The Delphi list: a criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. *Journal of Clinical Epidemiology* 1998;**51**(12):1235–41.

**Watkins 1991**

Watkins MA, Riddle DL, Lamb RL. Reliability of goniometric measurements and visual estimates of knee range of movement in a clinical setting. *Physical Therapy* 1991;**71**(2):90–7.

**WHO 2001**

World Health Organization. *ICF: International classification of functioning, disability and health*. Geneva: WHO, 2001.

\* Indicates the major publication for the study

## CHARACTERISTICS OF STUDIES

### Characteristics of included studies [ordered by study ID]

#### Beard 1994

Methods	<p>Method of randomisation: minimisation computer program. Stratification variables included gender, time since injury, frequency of sport participation and frequency of giving way.</p> <p>Assessor blinding: single examiner, blinded to group allocation.</p> <p>Participant blinding: patients unaware of differences in regimes.</p> <p>Loss to follow up: 7 patients</p> <p>Intention-to-treat analysis: yes, though data not available</p>
Participants	<p>Location: Nuffield Orthopaedic Hospital, Oxford, UK</p> <p>Participants: 50; 42 male, 8 female</p> <p>Age: mean 25 (range 16 to 49)</p> <p>Sports injury: no data.</p> <p>Inclusion: aged between 16 and 50 years, having an arthroscopically confirmed complete rupture of the anterior cruciate ligament</p> <p>Exclusion: complex meniscal tears, grade III collateral ligament damage, chondral damage, symptoms in the other knee or hips, ankles or feet, previous formal rehabilitation or operation for ACL deficiency, greater than 36 months post injury, or underlying neurological disease. Level of instability and general function subjectively worsened following diagnostic arthroscopy. 3 weeks post-arthroscopy: loss of full range of motion, unable to mobilise without walking aids, joint effusion or pain.</p>
Interventions	<p>First three weeks following arthroscopy all patients performed range of movement and gentle isometric/ isotonic quadriceps and hamstring exercises.</p> <p>Attendance commenced three weeks post arthroscopy. Twice weekly attendance for 12 weeks, 1 hour session (class) in physiotherapy department and daily home exercise plan (1 hour).</p> <p>(1) Traditional regime based on UK rehabilitation protocols.</p> <p>Strength: open kinetic chain exercises, graduated weight-resisted exercises, slight emphasis on hamstrings. Progression by increasing weight resistance.</p> <p>(2) Proprioceptive regime based on existing protocols and new adaptations. Facilitation of rapid contraction of hamstrings, improving dynamic stability. Progression by decreasing stability of starting position, increasing repetitions, removing visual feedback. Closed kinetic chain and functional exercises.</p> <p>Assigned: 25/25</p> <p>Assessed: 20 traditional, 23 proprioception</p>
Outcomes	<p>Length of follow up: 12 weeks</p> <p>Outcomes assessed at start (3 weeks post-arthroscopy) and 12 weeks (end of regime)</p> <p>Knee function: Lysholm score.</p> <p>Proprioception measured using Vicon Interfaced Knee Displacement Equipment.</p> <p>Knee laxity measured with KT-1000 arthrometer.</p> <p>Compliance: mean number of attendances in traditional group was 12 (SD 4), and proprioceptive group 14 (SD 6). No attempt was made to evaluate the compliance with the home exercise plan.</p>
Notes	CONSERVATIVE
<i>Risk of bias</i>	

**Beard 1994** (Continued)

Item	Authors' judgement	Description
Allocation concealment?	Yes	A - Adequate

**Beard 1998**

Methods	<p>Method of randomisation: minimisation computer program. Stratification variables included gender, sports level, sports frequency, knee stability (frequency of giving way) and time since injury.</p> <p>Assessor blinding: yes</p> <p>Participant blinding: yes</p> <p>Intention-to-treat analysis: included but did not alter the significance of the findings (data not presented)</p> <p>.</p> <p>Loss to follow up: 5</p>
Participants	<p>Location: Nuffield Orthopaedic Hospital, Oxford, UK</p> <p>Participants: 31 before losses. Of the 26 who completed the study, 21 male and 5 female.</p> <p>Age: median 28 (range 20-46). Mean age of supervised group 29, of home group 27.</p> <p>Sports injury: over 86% of participants sustained their injury during sport activities</p> <p>Inclusion: chronic ACL deficiency resulting in ACL reconstruction using the Bone-patella-bone (mid 1/3) technique.</p> <p>Exclusion: no details</p>
Interventions	<p>All patients seen in first week after discharge, randomised. For the first 4-6 weeks all patients completed same program, twice weekly supervised sessions in first two weeks, then once weekly thereafter. The decision to initiate group exercise was made by the treating therapist and based on the clinical status of the patient with respect to class exercises of known difficulty. A flexible 2 week window for initiation of the supervised sessions was chosen because the trial was designed to be pragmatic and reflect standard clinical practice.</p> <p>(1) Home exercises or alternative private facilities. Attended the rehabilitation department only for assessment, education, modification and progression.</p> <p>(2) Supervised twice weekly exercises, in a class setting in addition to the home program followed in (1) above. Discharged from the class between 16 and 18 weeks post-operatively. Patients completed at least 12 weeks under supervision.</p> <p>Assigned: 13/13</p> <p>Assessed:13/13</p>
Outcomes	<p>Length of follow up: 6 months</p> <p>Outcomes assessed at 2 weeks prior to surgery, 3 and 6 months post-surgery.</p> <p>Knee function: Lysholm and modified Tegner scores, International Knee Documentation Committee knee assessment form.</p> <p>Visual analogue scales for sports participation and activities of daily living.</p> <p>Muscle strength measure by dynamometry.</p> <p>Knee laxity measured with a KT-1000 arthrometer.</p> <p>Compliance: 5 patients lost to follow up. Patients did not complete compliance evaluation forms. Group (2) participants attended a median of 16 sessions (range 10 - 22).</p>



**Beard 1998** (Continued)

Notes	<p>POST-RECONSTRUCTION</p> <p>Rehabilitation program consisted of range of movement exercises, isometric (static) muscle contractions, graduated weight bearing, open and closed chain exercises for quadriceps and hamstrings, progression to proprioceptive and balance re-education, functional activities and preparation to return to sports at six months.</p>	
<i>Risk of bias</i>		
<b>Item</b>	<b>Authors' judgement</b>	<b>Description</b>
Allocation concealment?	Yes	A - Adequate

**Bynum 1995**

Methods	<p>Method of randomisation: sealed and numbered envelopes, pre-determined by computer generated table of random numbers.</p> <p>Assessor blinding: yes</p> <p>Participant blinding: no details</p> <p>Intention-to-treat analysis: not mentioned.</p> <p>Loss to follow up: Fifteen in total (3 patients did not complete the rehabilitation, and 12 failed to return for follow up).</p>	
Participants	<p>Location: Naval Medical Centre, California, USA</p> <p>Participants: 100: 97 completed the rehabilitation programme (88 male, 9 female).</p> <p>Age: mean age 26, range 18-48</p> <p>Sports injury: indication that patients participated in sports at recreational level, but not whether sport was the cause of injury.</p> <p>Inclusion: minimum age of 18, isolated ACL injury, normal contralateral knee, rigid graft fixation following arthroscopically assisted Bone-Patella-Bone middle 1/3 autograft.</p> <p>Exclusion: not stated</p>	
Interventions	<p>Following surgery, all patients were placed in a long leg hinged knee brace allowing 0 - 90° of motion. Continuous passive movement from 0 - 60° continued for 12 hours daily until discharge. Rehabilitation began on day one with passive, active assisted and active movement. Partial weight bearing was permitted, with progression to full weight bearing. At twelve months, patients returned to unrestricted sports.</p> <p>(1) Closed kinetic chain protocol using Sport Cord:</p> <p>week 6: stationary cycling;</p> <p>week 8: progressive resistance training with Sport Cord and jogging;</p> <p>week 12: jumping;</p> <p>week 24: running and sport-specific rehabilitation.</p> <p>(2) Open kinetic chain protocol:</p> <p>weeks 0 - 3: isometric and isotonic exercises;</p> <p>week 6: low resistance stationary cycling; week 8: isokinetic hamstrings;</p> <p>week 12: unrestricted isotonic;</p> <p>week 24: unrestricted progressive resistance training;</p> <p>7 - 8 months: running and sport specific rehabilitation.</p> <p>Assigned: 50/47</p> <p>Assessed: 44/41 for subjective and objective measurements at 12 months follow up.</p>	

**Bynum 1995** (Continued)

Outcomes	<p>Length of follow up: mean 19 months, range 12 to 36.</p> <p>Outcomes assessed: pre- and post-operative evaluations were performed at 3-monthly intervals for the first 12 months and thereafter, yearly.</p> <p>Knee function: Lysholm and Tegner Activity scores, Overall Patient Satisfaction survey.</p> <p>Knee laxity measured with KT-1000 arthrometer.</p> <p>Range of movement and patellofemoral tenderness also measured.</p>	
Notes	<p>POST-RECONSTRUCTION</p> <p>No data available for compliance or attendance.</p>	
<b>Risk of bias</b>		
<b>Item</b>	<b>Authors' judgement</b>	<b>Description</b>
Allocation concealment?	Unclear	B - Unclear

**Fischer 1998**

Methods	<p>Method of randomisation: not stated</p> <p>Assessor blinding: not stated</p> <p>Participant blinding: not possible</p> <p>Intention-to-treat analysis: not mentioned.</p> <p>Loss to follow-up: 1</p>	
Participants	<p>Location: Minneapolis Sports Medicine Centre, Minneapolis, USA.</p> <p>Participants: 54, 28 male, 26 female.</p> <p>Age: mean age 30, range 15 to 44.</p> <p>Sports injury: no data available.</p> <p>Inclusion: over the age 15, minimum period of 6 weeks between injury and surgery, confirmed isolated complete ACL rupture and able to give informed consent.</p> <p>Exclusion: previous repair or reconstruction of knee ligaments, professional, collegiate or elite athletes, and any complicating medical conditions.</p>	
Interventions	<p>All patients were given a home exercise program divided into four phases:</p> <p>1 restoration of range of motion;</p> <p>2 functional strengthening;</p> <p>3 advanced functional strengthening;</p> <p>4 speed and agility training.</p> <p>All patients returned for follow up at three days post-operatively.</p> <p>Patients were allocated into one of two groups.</p> <p>(1) Home group - prescribed six physical therapy visits (weeks 1, 2, 3, 4, 6, and 12). Average of 5 visits, range 3 - 7.</p> <p>(2) Clinic group - 24 physical therapy appointments in first 6 months. Average 19.9 visits, range 10-28.</p> <p>Assigned: 27/27</p> <p>Assessed: 27/26</p>	

**Fischer 1998** (Continued)

Outcomes	<p>Length of follow up: 6 months.          Outcomes assessed at 1, 6, 12, 18 and 24 weeks.          Lysholm score (12 and 24 weeks), subjective health status questionnaire (24 weeks)          Noyes' one legged hop test (24 weeks).          Knee laxity measured with KT-1000 arthrometer.          Range of motion.          Thigh atrophy.          Compliance: no patients were excluded.</p>	
Notes	<p>POST-RECONSTRUCTION          All patients underwent arthroscopically assisted Bone-Patella-Bone autograft (4 underwent allograft).</p>	
<b>Risk of bias</b>		
<b>Item</b>	<b>Authors' judgement</b>	<b>Description</b>
Allocation concealment?	Unclear	B - Unclear

**Fitzgerald 2000**

Methods	<p>Method of randomisation: computer generated random number list.          Assessor blinding: not stated          Participant blinding: not stated          Intention-to-treat analysis: not mentioned          Loss to follow up: 2</p>	
Participants	<p>Location: University of Delaware Physical Therapy Clinic, Newark, USA.          Participants: 28; of 26, 20 males and 6 females.          Age: standard group mean age 27.6 (SD 11.8) range 15-34; perturbation group mean age 29.2 (SD 11.5) range 18-57          Sports injury: all patients participated in sports. Not stated is this was cause of injury.          Inclusion: ACL rupture.          Exclusion: onset longer than 6 months, concurrent multiple ligament/meniscal damage, &lt;50 hours sports per year, less than 3 mm side-to-side laxity with arthrometry testing.</p>	
Interventions	<p>Description: patients randomly allocated into two groups. All patients completed the training in a 5 week period, with 10 sessions allocated in a rehabilitation gym.          (1) Standard treatment group: resistive muscle strengthening, cardiovascular endurance training, agility skill training, sport specific training.          (2) Perturbation group: standard program plus specific balance and proprioception training.          Assigned: 15/13          Assessed: 14/12</p>	
Outcomes	<p>Length of follow up: 5 weeks.          Outcomes assessed at 5 weeks.          Knee Outcome Survey Activities of Daily Living Scale, Sports Activity Scale and Global rating of knee function.          Maximal voluntary isometric contraction - Dynamometer.</p>	

**Fitzgerald 2000** (Continued)

	Single leg hop test. Knee laxity measured with KT-2000 arthrometer. Compliance: subjects attended for ten sessions of treatment - no indication given of level of compliance.	
Notes	CONSERVATIVE	
<b>Risk of bias</b>		
<b>Item</b>	<b>Authors' judgement</b>	<b>Description</b>
Allocation concealment?	Unclear	B - Unclear

**Hooper 2001**

Methods	Method of randomisation: block randomisation (randomised blocks of four subjects at a time to ensure that nearly equal numbers were assigned to each group). Assessor blinding: unclear Participant blinding: not stated Intention-to-treat analysis: not mentioned Loss to follow up: 6	
Participants	Location: Department of Health Sciences, University of East London, UK. Participants: 43; of 37, 29 male and 8 female. Age: no data available. Sports injury: no data available Inclusion: ACL reconstruction by either a) arthroscopically assisted Bone-Patella-Bone middle 1/3 auto-graft or b) ligamentous augmentation device technique. Patient able to flex knee greater than 90° and walk unaided. Exclusion: history of pathological problems in the contralateral limb, history to the PCL in the injured limb, any post-operative complications.	
Interventions	Patients all underwent gait analysis at 2 weeks post-operatively and then allocated into one of two groups undertaking rehabilitation 3 times per week, for four weeks. (1) Closed kinetic chain group - unilateral resistance hip/knee extensor training (3 sets, 20 repetitions, 90°-0°), stationary cycling, balance and proprioceptive training. (2) Open kinetic chain (OKC) group - hip and knee extension with weights/machines (velocity controlled 60°/s concentric and 30°/s eccentric), stationary cycling, balance and proprioceptive training. Assigned: 18/19 Assessed: 18/19 with exception of stair ascent descent with two drop-outs (not stated which group).	
Outcomes	Length of follow up: 4 weeks Outcomes assessed at 2 weeks and 6 weeks post-operatively. Hughston Clinic (Knee) visual analogue scale (6 weeks). Gait analysis ( 2 and 6 weeks). Stair ascent/descent (? only at 6 weeks). Compliance: not stated.	
Notes	POST-RECONSTRUCTION	

**Hooper 2001** (Continued)

<i>Risk of bias</i>		
Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

**Mikkelsen 2000**

Methods	Method of randomisation: unclear Assessor blinding: unclear Participant blinding: unlikely. Intention-to-treat analysis: not mentioned. Loss to follow up: none
Participants	Location: Karolinska Hospital, Stockholm, Sweden. Participants: 44, 34 males, 10 females Age: range 18-40 Sports injury: all patients (except one) were athletes. Inclusion: chronic ACL injury resulting in reconstruction. Exclusion: previous serious knee injury, concomitant other injury affecting rehabilitation, unhealthy contralateral limb.
Interventions	Description: all patients underwent the same rehabilitation protocol for the first five weeks (range of motion, flexibility training, proprioceptive and balance training, closed kinetic chain exercises and hamstring training). At week 5, patients were randomly assigned into one of two groups. (1) Standard group - functional exercises, jogging, running, sport-specific exercises. (2) Isokinetic group - standard protocol plus open kinetic chain isokinetic quadriceps (concentric and eccentric) training until 6 months after surgery. Assigned: 22/22 Assessed: 22/22
Outcomes	Length of follow up: Mean 31.0 ± 9.7 months (questionnaire). Outcomes assessed pre-operatively and at 6 months. Function: return to sports questionnaire. Knee laxity measured with KT-1000 arthrometer. Isokinetic muscle torque measured with dynamometry. Compliance: not stated.
Notes	POST-RECONSTRUCTION All patients underwent arthroscopically assisted Bone-Patella-Bone middle 1/3 autograft.

<i>Risk of bias</i>		
Item	Authors' judgement	Description
Allocation concealment?	Unclear	B - Unclear

**Schenck 1997**

Methods	Method of randomisation: lottery numbers 1-100. Odd and even split into two groups. Assessor blinding: independent observer ?blinded to allocation. Participant blinding: not possible. Intention-to-treat analysis: not mentioned. Loss to follow up: none.	
Participants	Location: University of Texas, Texas, USA. Participants: 37, 28 male and 9 female. Age: mean 24.1 years, range 18 to 32 years. Sports injury: no details. Inclusion: aged over 18 years, torn ACL and knee instability resulting in reconstruction. Exclusion: no other details.	
Interventions	All patients were given pre-operative education and followed similar goals - obtaining full range of motion, normal gait, and quadriceps/hamstrings strengthening. (1) Clinic group - 3 visits per week over 6 weeks. Averaged 14.2 visits (range 6-40). Average cost \$930. (2) Home group - individual functional exercise programs monitored via clinic visits by a physical therapist (determined by visits at 3 and 10 days post-operatively). Averaged 2.85 visits (range 0 - 6). Average cost \$225. Assigned: 15/22 Assessed: 15/22	
Outcomes	Length of follow up: 1 year. Outcomes assessed pre-operatively, 3 months post-operatively and 1 year post-operatively. Lysholm knee rating scale. Sickness Impact Profile Questionnaire. Knee range of motion. Pain: visual analogue scale. Single leg hop test. Knee laxity measured with KT-1000 arthrometer. Compliance: measured at 1 year post-operatively.	
Notes	POST-RECONSTRUCTION Reconstruction: arthroscopically assisted Bone-Patella-Bone middle 1/3 autograft	
<b><i>Risk of bias</i></b>		
<b>Item</b>	<b>Authors' judgement</b>	<b>Description</b>
Allocation concealment?	Unclear	B - Unclear

**Tovin 1994**

Methods	Method of randomisation: coin toss. Patients allocated in pairs into opposite groups. Assessor blinding: some blinding occurred. Participant blinding: not possible. Intention-to-treat analysis: not mentioned. Loss to follow up: 1	
Participants	Location: Piedmont Hospital, Atlanta, USA. Participants: 20, 14 male and 6 female. Age: mean age 29.0 (SD 7.8), range 16 to 44. Sports injury: no details. Inclusion: ACL reconstruction using Bone-Patella-Bone autograft. Exclusion: prior ACL surgery to either knee or meniscal repair at time of surgery.	
Interventions	All patients followed the same rehabilitation program in the first post-operative group (range of motion exercises, stretches, strengthening exercises and gait retraining). In weeks 2 to 8, patients were assigned to one of two groups, and sessions were 3 times per week. (1) Land based group - cycling, gait training, side steps and step ups, hip strengthening, and hamstring strengthening (closed chain). (2) Pool based group - as for land based group, but within the pool (closed chain). Assigned: 10/10 Assessed: 9/10	
Outcomes	Length of follow up: 8 weeks. Outcomes assessed at various points (see below). Lysholm Score and functional questionnaire (8 weeks). Joint laxity measured with KT-1000 arthrometer (pre-op and 8 weeks). Isometric and isokinetic peak knee torques measured with dynamometry (8 weeks). Passive range of motion (2, 4, 6 and 8 weeks). Thigh girth (pre-op and 2, 4, 6 and 8 weeks). Compliance: not stated.	
Notes	POST-RECONSTRUCTION	
<b><i>Risk of bias</i></b>		
<b>Item</b>	<b>Authors' judgement</b>	<b>Description</b>
Allocation concealment?	Unclear	B - Unclear

ACL: anterior cruciate ligament

### Characteristics of excluded studies *[ordered by study ID]*

Blanpied 2000	RCT. None of the primary outcome measures for this review were reported.
Brandsson 2001	RCT. 50 patients following ACL reconstruction, comparing use of knee brace. Not in scope of review.
Decker 2004	RCT. 16 patients following ACL reconstruction, comparing two gait retraining protocols. None of the primary outcome measures for this review were reported.
Donatelli 1996	RCT. None of the primary outcome measures for this review were reported.
Draper 1990	RCT. Primary outcome measure not reported. Study compares use of electrotherapy modalities which are not in the scope of this review.
Ekstrand 1990	RCT. Mixed knee pathologies (ACL ± meniscus).
Frobose 1993	RCT. None of the primary outcome measures for this review were reported.
Hehl 1995	RCT. None of the primary outcome measures for this review were reported.
Hehl 2003	Data of the control group was from an earlier study, not a concurrent control group.
Hooper 2002	RCT. None of the primary outcome measures for this review were reported.
Knaepler 1994	RCT. Mixed knee pathologies (ACL ± MCL ± LCL ± meniscus). Some participants were aged under 16.
McClintock 1995	RCT. None of the primary outcome measures for this review were reported.
Meyers 2002	RCT. None of the primary outcome measures for this review were reported.
Moller 2001	RCT. 62 patients following ACL reconstruction comparing use of knee brace. Not in scope of review.
Morrissey 2000	RCT. None of the primary outcome measures for this review were reported.
Morrissey 2002	RCT. None of the primary outcome measures for this review were reported.
Oberg 1991	RCT. None of the primary outcome measures for this review were reported.
Ohta 2003	RCT. Comparing effects of restricted blood flow during muscular training. Not in scope of review. None of the primary outcome measures for this review were reported.
Risberg 1999	RCT. 60 patients following ACL reconstruction, comparing use of knee brace. Mixed population (ACL ± MCL ± meniscus) included. Not in scope of review.
Thoméé 1987	RCT. None of the primary outcome measures for this review were reported.
Timm 1997	RCT. None of the primary outcome measures for this review were reported.



(Continued)

Tsaklis 2002	RCT. None of the primary outcome measures for this review were reported.
Zatterstrom 1998	RCT. Mixed knee pathologies (ACL ± MCL ± meniscus). Some participants were under the age of 16.

ACL: anterior cruciate ligament  
LCL: lateral collateral ligament  
MCL: medial collateral ligament  
RCT: randomised control trial

## DATA AND ANALYSES

### Comparison 1. Conservative: supplementary proprioceptive training versus traditional regime

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Lysholm score (0 to 100; 100 being greatest function) at 12 weeks after treatment	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

### Comparison 2. Conservative: supplementary perturbation training versus standard regime

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Knee Outcome Scores	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
1.1 Activities of Daily Living scores (0 to 100%; 100% representing greater function): post treatment	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
1.2 Activities of Daily Living scores (0 to 100%; 100% representing greater function): 6 month follow up	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
1.3 Sports Activity scores (0 to 100%; 100% representing greater level of activity): post treatment	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
1.4 Sports Activity scores (0 to 100%; 100% representing greater level of activity): 6 month follow up	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
1.5 Global Rating of Knee Function (0 to 100%; 100% representing pre-injury function): post treatment	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
1.6 Global Rating of Knee Function (0 to 100%; 100% representing pre-injury function): 6 month follow up	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
2 Return to full activity at 6 month follow up	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
3 Isometric MVIC quadriceps (% group mean)	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
3.1 Post-treatment	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
3.2 Follow-up at 6 months	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable

4 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
--	---	--	-------------------------------------	---------------------

### Comparison 3. Reconstruction: home based versus supervised rehabilitation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Lysholm scores (0 to 100; 100 being greatest function)	3		Mean Difference (IV, Fixed, 95% CI)	Subtotals only
1.1 12 weeks post surgery	1	54	Mean Difference (IV, Fixed, 95% CI)	-1.0 [-5.61, 3.61]
1.2 6 months post surgery	2	80	Mean Difference (IV, Fixed, 95% CI)	1.46 [-3.19, 6.10]
1.3 1 year post surgery	1	37	Mean Difference (IV, Fixed, 95% CI)	Not estimable
2 Tegner score (% change from pre-injury level of activity) at 6 months after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
3 Sickness Impact Profile at 1 year after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4 Muscle strength: torque ratio (% of control limb)	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4.1 Quadriceps at 3 months after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
4.2 Quadriceps at 6 months after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
4.3 Hamstrings at 3 months after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
4.4 Hamstrings at 6 months after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
5 Knee range of movement (degrees)	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
5.1 at 6 weeks after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
5.2 at 12 weeks after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
5.3 at 18 weeks after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
5.4 at 24 weeks after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
6 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected

#### Comparison 4. Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Lysholm score (0 to 100; 100 being greatest function) at 1+ year follow up	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2 Tegner score (0 to 10; 10 being greatest level of activity) at 1+ year follow up	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
3 Hughston Clinic Functional Score (0 to 100; 100 being no disability) at 6 weeks after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
4 Patellofemoral pain severe enough to restrict activity at 1 year	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
5 Knee laxity: anterior sagittal translation (mm). Between limb difference at 1+ year follow up	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
5.1 Arthrometry with 20 lbs torque	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
5.2 Arthrometry with max torque	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
6 Lachman test: negative at 1 year	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected

#### Comparison 5. Reconstruction: closed kinetic chain versus closed and open kinetic chain rehabilitation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Return to pre-injury level of sport at 31 months after surgery	1		Risk Ratio (M-H, Fixed, 95% CI)	Totals not selected
2 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
3 Isokinetic quadriceps strength (Nm) testing at 6 months after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
3.1 30°/second concentric	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
3.2 30°/second eccentric	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
3.3 120°/second concentric	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
3.4 120°/second eccentric	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
3.5 240°/second concentric	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
3.6 240°/second eccentric	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable

## Comparison 6. Reconstruction: land based versus water based rehabilitation

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Lysholm score (0 to 100; 100 being greatest function) at 8 weeks after surgery	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2 Muscle strength at 8 weeks post surgery (% of contralateral limb)	1		Mean Difference (IV, Fixed, 95% CI)	Totals not selected
2.1 Peak isokinetic torque at 90°/s: flexion	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
2.2 Peak isokinetic torque at 90°/s: extension	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
2.3 Peak isometric torque: flexion (knee flexed 60°)	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable
2.4 Peak isometric torque: extension (knee flexed 85°)	1		Mean Difference (IV, Fixed, 95% CI)	Not estimable

### Analysis 1.1. Comparison 1 Conservative: supplementary proprioceptive training versus traditional regime, Outcome 1 Lysholm score (0 to 100; 100 being greatest function) at 12 weeks after treatment.

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 1 Conservative: supplementary proprioceptive training versus traditional regime

Outcome: 1 Lysholm score (0 to 100; 100 being greatest function) at 12 weeks after treatment

Study or subgroup	Proprioceptive		Traditional		Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
	N	Mean(SD)	N	Mean(SD)		
Beard 1994	23	85 (13)	20	78 (22)		7.00 [ -4.01, 18.01 ]

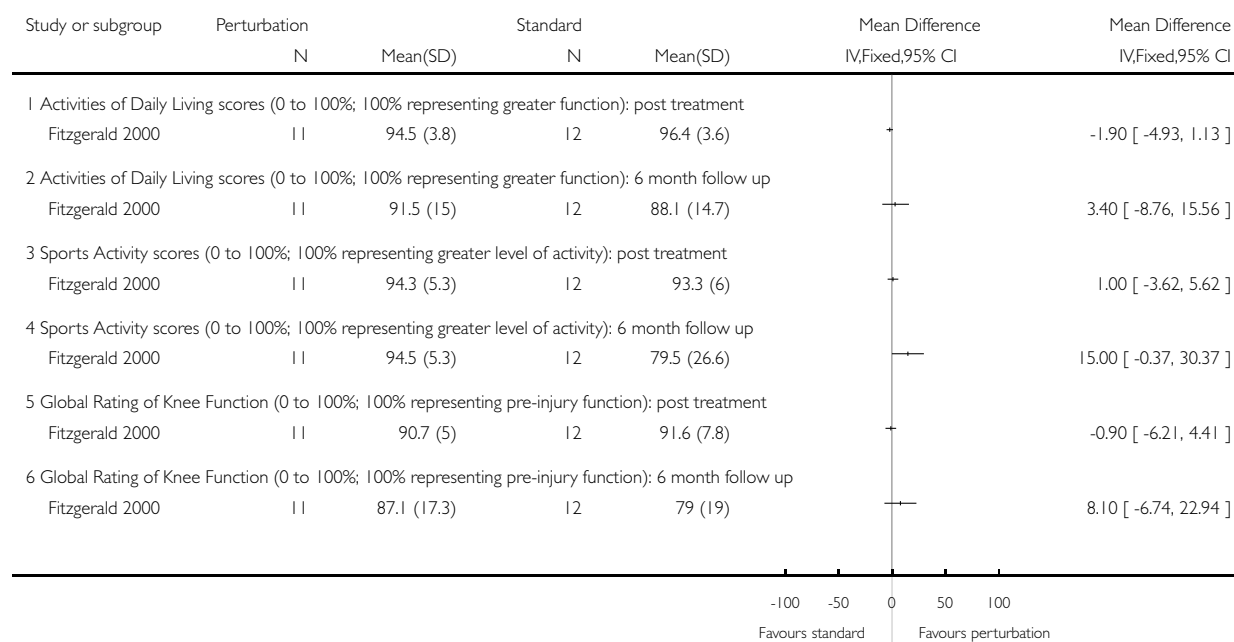
-100   -50   0   50   100  
Favours traditional   Fav. proprioceptive

### Analysis 2.1. Comparison 2 Conservative: supplementary perturbation training versus standard regime, Outcome 1 Knee Outcome Scores.

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 2 Conservative: supplementary perturbation training versus standard regime

Outcome: 1 Knee Outcome Scores

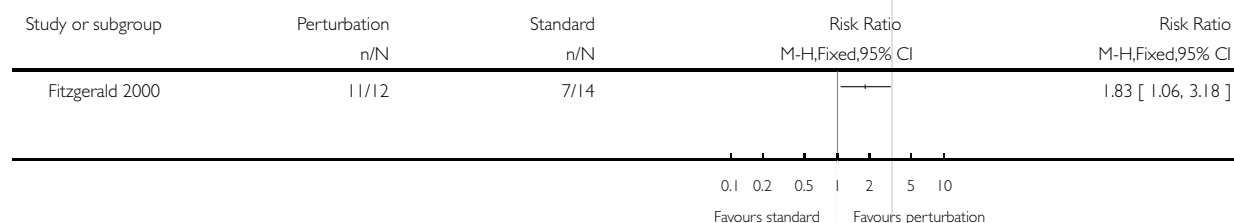


### Analysis 2.2. Comparison 2 Conservative: supplementary perturbation training versus standard regime, Outcome 2 Return to full activity at 6 month follow up.

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 2 Conservative: supplementary perturbation training versus standard regime

Outcome: 2 Return to full activity at 6 month follow up

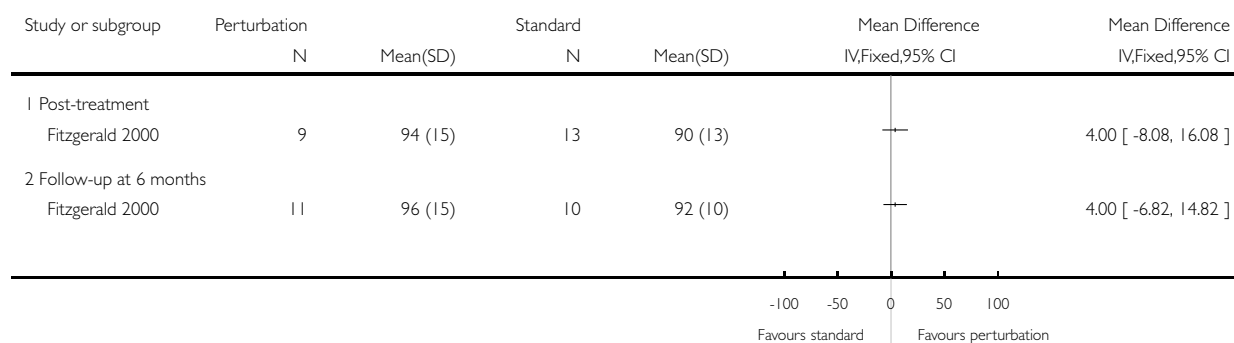


**Analysis 2.3. Comparison 2 Conservative: supplementary perturbation training versus standard regime, Outcome 3 Isometric MVIC quadriceps (% group mean).**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 2 Conservative: supplementary perturbation training versus standard regime

Outcome: 3 Isometric MVIC quadriceps (% group mean)

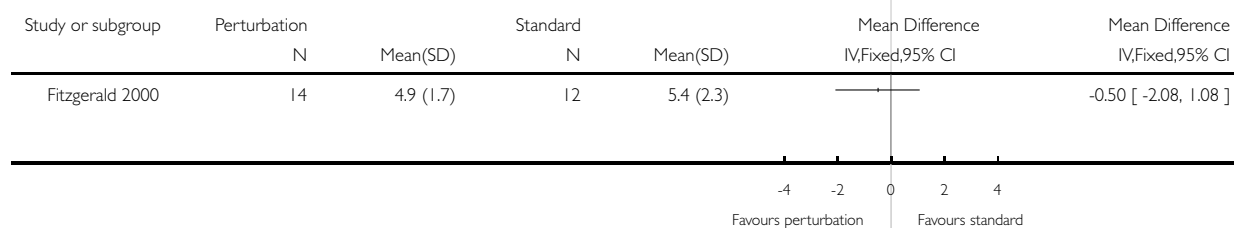


**Analysis 2.4. Comparison 2 Conservative: supplementary perturbation training versus standard regime, Outcome 4 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 2 Conservative: supplementary perturbation training versus standard regime

Outcome: 4 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months

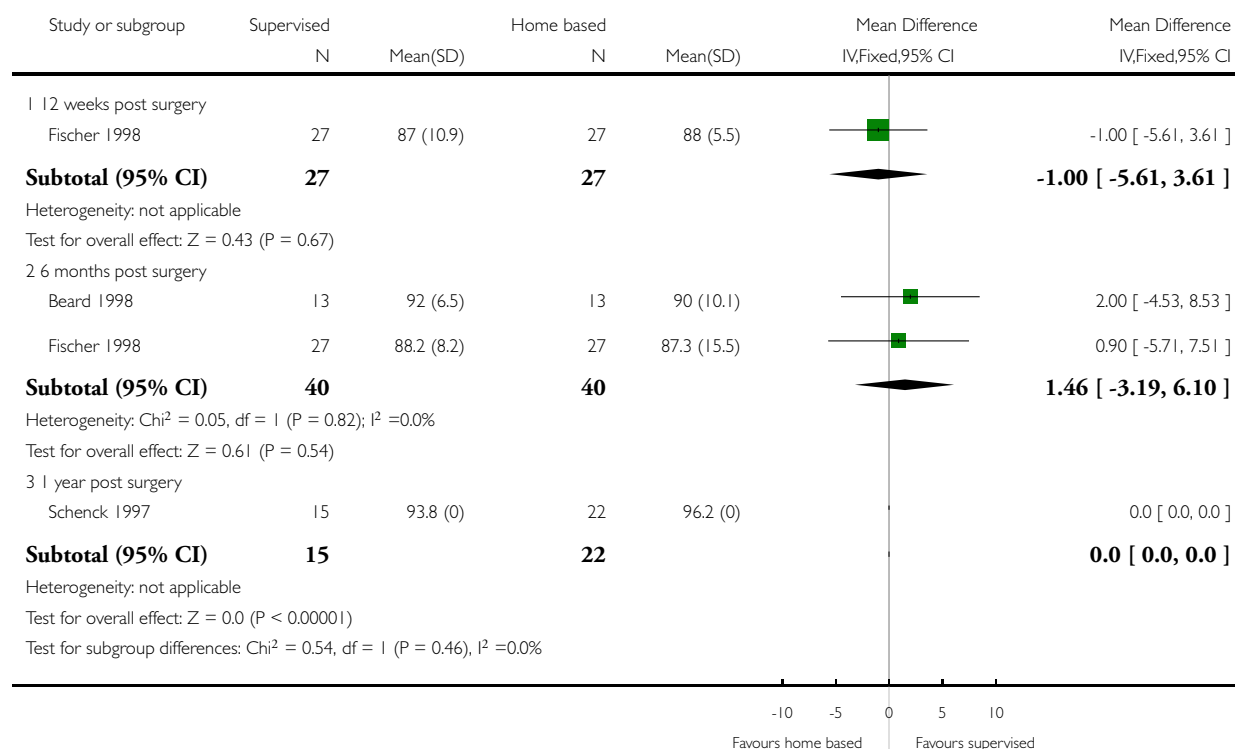


### Analysis 3.1. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 1 Lysholm scores (0 to 100; 100 being greatest function).

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 3 Reconstruction: home based versus supervised rehabilitation

Outcome: 1 Lysholm scores (0 to 100; 100 being greatest function)

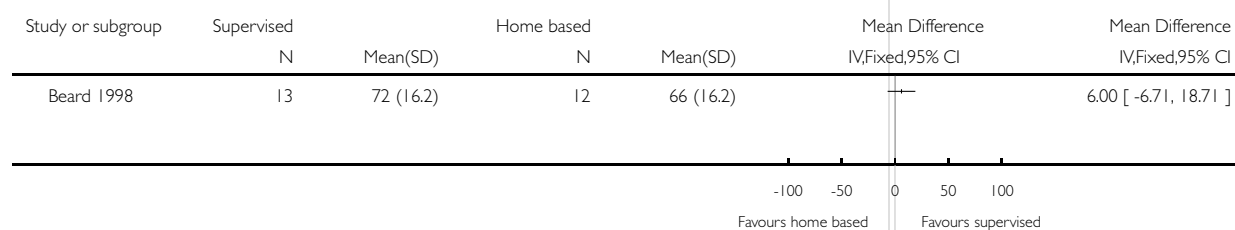


### Analysis 3.2. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 2 Tegner score (% change from pre-injury level of activity) at 6 months after surgery.

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 3 Reconstruction: home based versus supervised rehabilitation

Outcome: 2 Tegner score (% change from pre-injury level of activity) at 6 months after surgery





**Analysis 3.3. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 3 Sickness Impact Profile at 1 year after surgery.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 3 Reconstruction: home based versus supervised rehabilitation

Outcome: 3 Sickness Impact Profile at 1 year after surgery

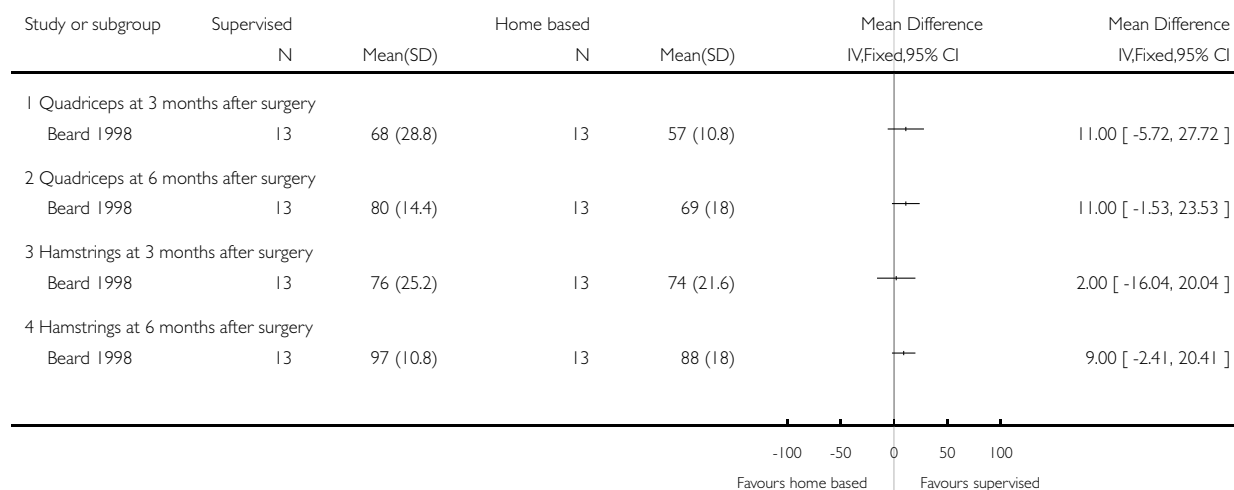


**Analysis 3.4. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 4 Muscle strength: torque ratio (% of control limb).**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 3 Reconstruction: home based versus supervised rehabilitation

Outcome: 4 Muscle strength: torque ratio (% of control limb)

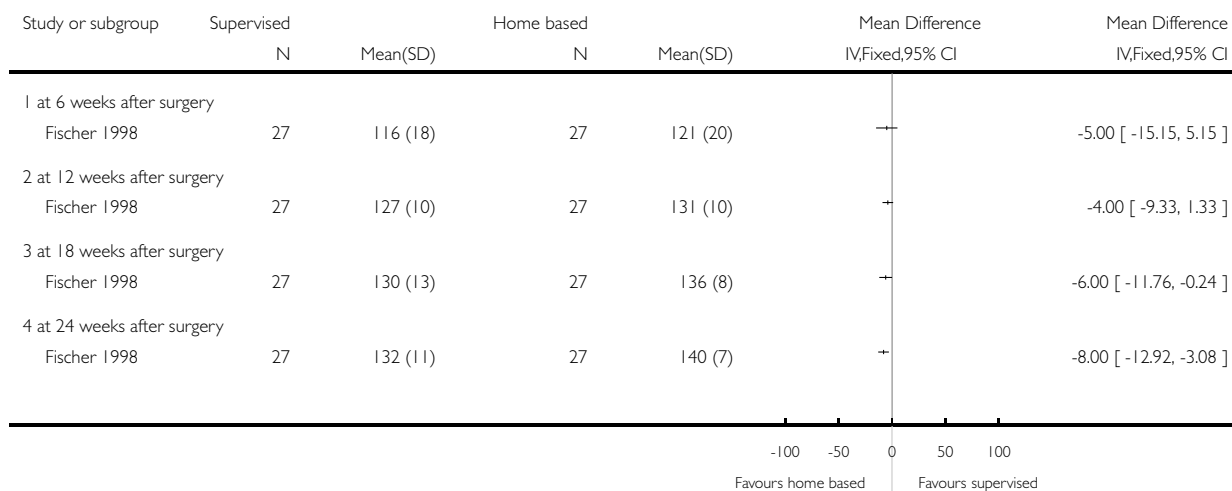


**Analysis 3.5. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 5 Knee range of movement (degrees).**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 3 Reconstruction: home based versus supervised rehabilitation

Outcome: 5 Knee range of movement (degrees)

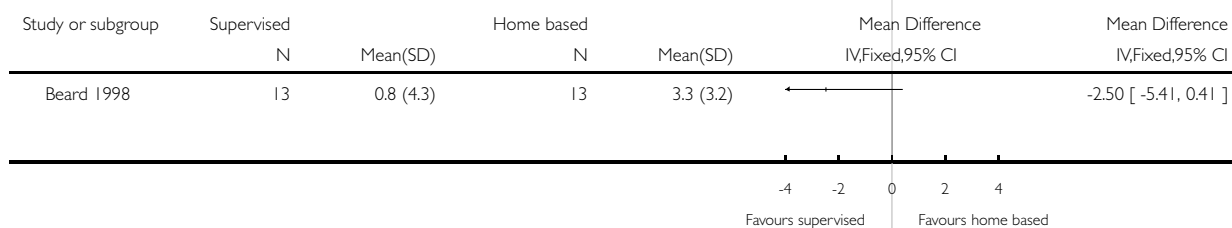


**Analysis 3.6. Comparison 3 Reconstruction: home based versus supervised rehabilitation, Outcome 6 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months after surgery.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 3 Reconstruction: home based versus supervised rehabilitation

Outcome: 6 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months after surgery



**Analysis 4.1. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 1 Lysholm score (0 to 100; 100 being greatest function) at 1+ year follow up.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation

Outcome: 1 Lysholm score (0 to 100; 100 being greatest function) at 1+ year follow up

Study or subgroup	Open chain		Closed chain		Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
	N	Mean(SD)	N	Mean(SD)		
Bynum 1995	41	86 (0)	44	88 (0)		0.0 [ 0.0, 0.0 ]

**Analysis 4.2. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 2 Tegner score (0 to 10; 10 being greatest level of activity) at 1+ year follow up.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation

Outcome: 2 Tegner score (0 to 10; 10 being greatest level of activity) at 1+ year follow up

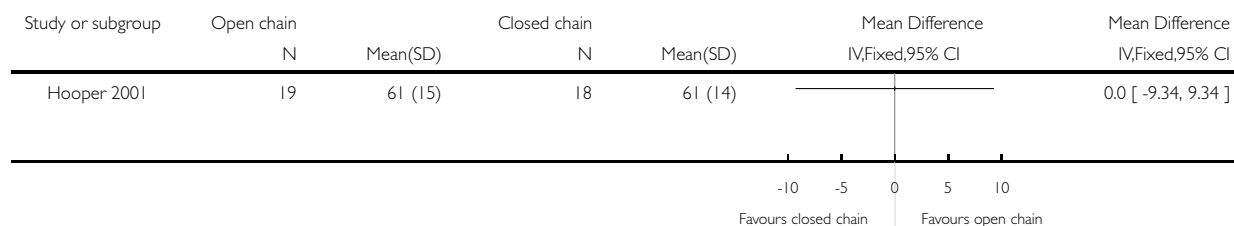
Study or subgroup	Open chain		Closed chain		Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
	N	Mean(SD)	N	Mean(SD)		
Bynum 1995	41	6 (0)	44	6 (0)		0.0 [ 0.0, 0.0 ]

**Analysis 4.3. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 3 Hughston Clinic Functional Score (0 to 100; 100 being no disability) at 6 weeks after surgery.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation

Outcome: 3 Hughston Clinic Functional Score (0 to 100; 100 being no disability) at 6 weeks after surgery

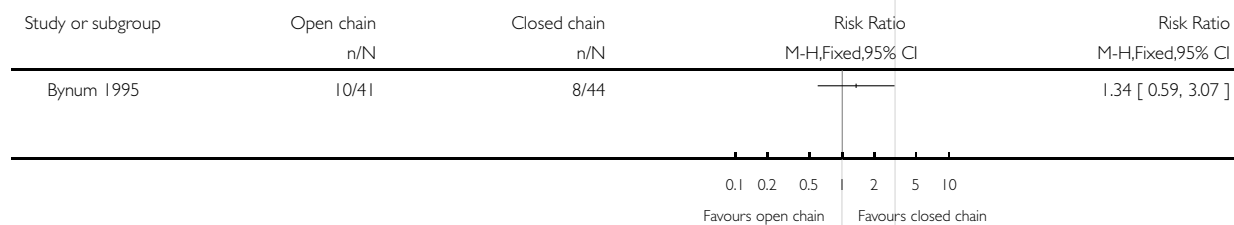


**Analysis 4.4. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 4 Patellofemoral pain severe enough to restrict activity at 1 year.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation

Outcome: 4 Patellofemoral pain severe enough to restrict activity at 1 year



**Analysis 4.5. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 5 Knee laxity: anterior sagittal translation (mm). Between limb difference at 1+ year follow up.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation

Outcome: 5 Knee laxity: anterior sagittal translation (mm). Between limb difference at 1+ year follow up

Study or subgroup	Open chain		Closed chain		Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
	N	Mean(SD)	N	Mean(SD)		
1 Arthrometry with 20 lbs torque						
Bynum 1995	32	2.2 (0)	32	1.1 (0)		0.0 [ 0.0, 0.0 ]
2 Arthrometry with max torque						
Bynum 1995	32	3.3 (0)	32	1.6 (0)		0.0 [ 0.0, 0.0 ]

-4   -2   0   2   4  
Favours open chain   Favours closed chain

**Analysis 4.6. Comparison 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation, Outcome 6 Lachman test: negative at 1 year.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 4 Reconstruction: closed kinetic chain versus open kinetic chain rehabilitation

Outcome: 6 Lachman test: negative at 1 year

Study or subgroup	Open chain	Closed chain	Risk Ratio M-H,Fixed,95% CI	Risk Ratio M-H,Fixed,95% CI
	n/N	n/N		
Bynum 1995	28/32	30/32		0.93 [ 0.80, 1.09 ]

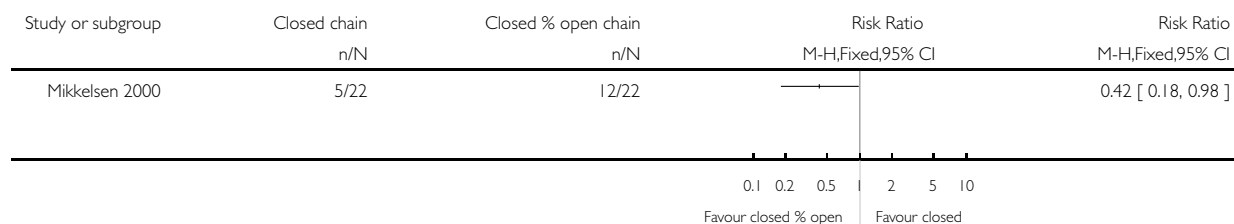
0.5   0.7   1.5   2  
Favours closed chain   Favours open chain

**Analysis 5.1. Comparison 5 Reconstruction: closed kinetic chain versus closed and open kinetic chain rehabilitation, Outcome 1 Return to pre-injury level of sport at 31 months after surgery.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 5 Reconstruction: closed kinetic chain versus closed and open kinetic chain rehabilitation

Outcome: 1 Return to pre-injury level of sport at 31 months after surgery

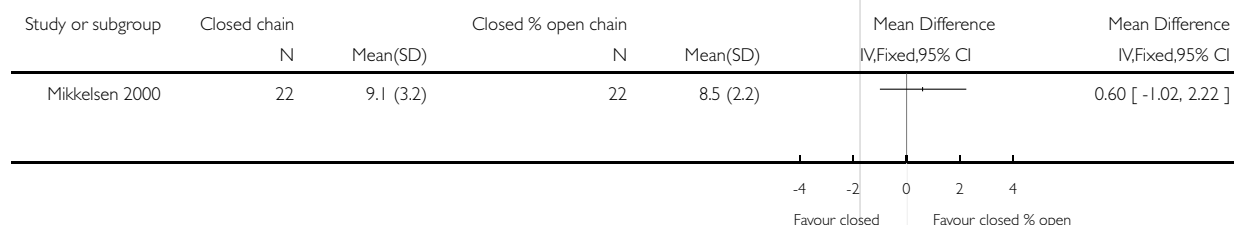


**Analysis 5.2. Comparison 5 Reconstruction: closed kinetic chain versus closed and open kinetic chain rehabilitation, Outcome 2 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months after surgery.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 5 Reconstruction: closed kinetic chain versus closed and open kinetic chain rehabilitation

Outcome: 2 Knee laxity: anterior sagittal translation (mm). Between limb difference at 6 months after surgery

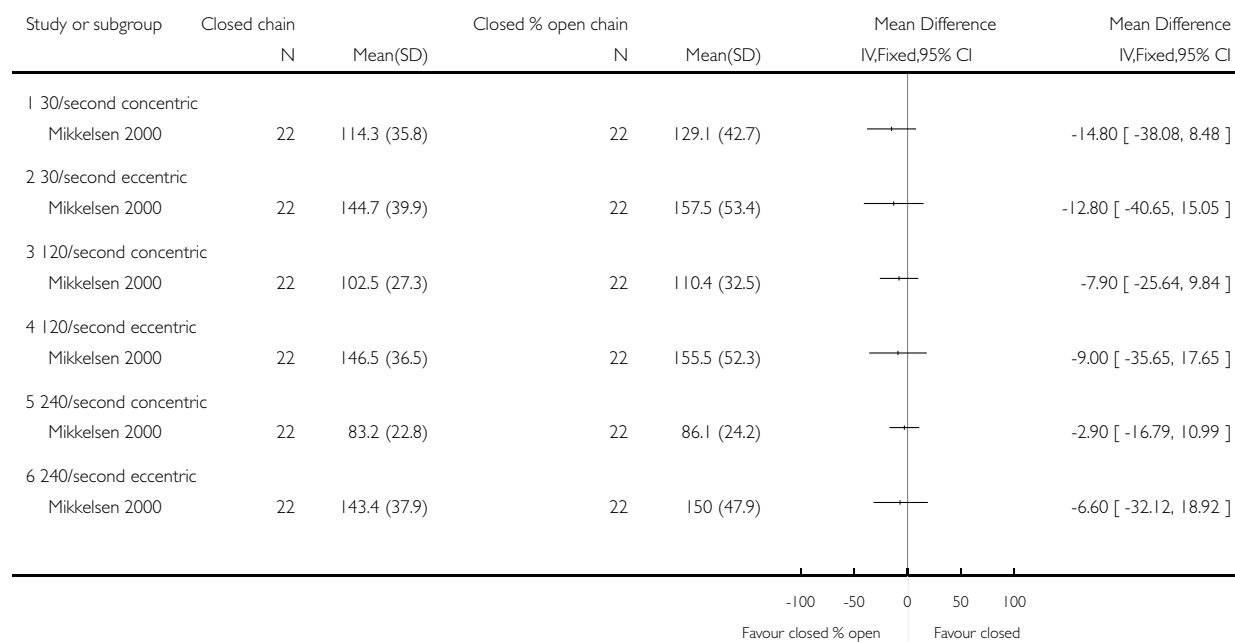


**Analysis 5.3. Comparison 5 Reconstruction: closed kinetic chain versus closed and open kinetic chain rehabilitation, Outcome 3 Isokinetic quadriceps strength (Nm) testing at 6 months after surgery.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 5 Reconstruction: closed kinetic chain versus closed and open kinetic chain rehabilitation

Outcome: 3 Isokinetic quadriceps strength (Nm) testing at 6 months after surgery

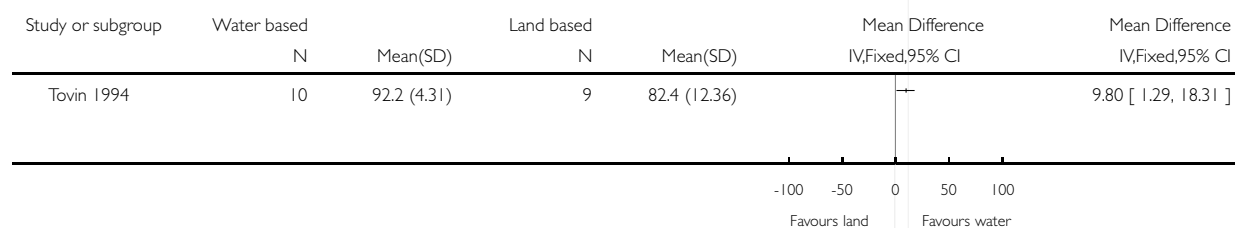


**Analysis 6.1. Comparison 6 Reconstruction: land based versus water based rehabilitation, Outcome 1 Lysholm score (0 to 100; 100 being greatest function) at 8 weeks after surgery.**

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 6 Reconstruction: land based versus water based rehabilitation

Outcome: 1 Lysholm score (0 to 100; 100 being greatest function) at 8 weeks after surgery



## Analysis 6.2. Comparison 6 Reconstruction: land based versus water based rehabilitation, Outcome 2 Muscle strength at 8 weeks post surgery (% of contralateral limb).

Review: Exercise for treating isolated anterior cruciate ligament injuries in adults

Comparison: 6 Reconstruction: land based versus water based rehabilitation

Outcome: 2 Muscle strength at 8 weeks post surgery (% of contralateral limb)

Study or subgroup	Water based		Land based		Mean Difference IV,Fixed,95% CI	Mean Difference IV,Fixed,95% CI
	N	Mean(SD)	N	Mean(SD)		
1 Peak isokinetic torque at 90/s: flexion						
Tovin 1994	10	81.7 (11.1)	9	96.4 (13.5)	-14.70	[-25.89, -3.51]
2 Peak isokinetic torque at 90/s: extension						
Tovin 1994	10	50.6 (18.1)	9	56.1 (19.2)	-5.50	[-22.33, 11.33]
3 Peak isometric torque: flexion (knee flexed 60)						
Tovin 1994	10	83.7 (10.6)	9	85.1 (9.1)	-1.40	[-10.26, 7.46]
4 Peak isometric torque: extension (knee flexed 85)						
Tovin 1994	10	42.8 (12.7)	9	43.1 (11.6)	-0.30	[-11.23, 10.63]

-100 -50 0 50 100  
Favours land Favours water

## APPENDICES

### Appendix I. Search strategy for MEDLINE

1. Anterior Cruciate Ligament/
2. Soft Tissue Injuries/
3. "Sprains and Strains"/
4. Athletic Injuries/
5. Knee Injuries/
6. Knee/ or Knee Joint/
7. or/2-6
8. (anterior adj3 cruciate\$1).tw.
9. and/7-8
10. or/1,9
11. Exercise/
12. Rehabilitation/
13. Physical Therapy Techniques/
14. Exercise therapy/
15. \*Clinical Protocols/
16. \*"Recovery of Function"/
17. (physiotherap\$ or physical therap\$ or rehab\$ or training or exercis\$).tw.
18. (rh or th).fs.
19. or/11-18
20. and/10,19



21. randomized controlled trial.pt.
22. controlled clinical trial.pt.
23. Randomized Controlled Trials/
24. Random Allocation/
25. Double-Blind Method/
26. Single-Blind Method/
27. or/21-26
28. Animal/ not Human/
29. 27 not 28
30. clinical trial.pt.
31. exp Clinical Trials/
32. (clinic\$ adj25 trial\$).tw.
33. ((singl\$ or doubl\$ or trebl\$ or tripl\$) adj (mask\$ or blind\$)).tw.
34. Placebos/
35. placebo\$.tw.
36. random\$.tw.
37. Research Design/
38. (latin adj square).tw.
39. or/30-38
40. 39 not 28
41. 40 not 29
42. and/20,29
43. and/20,41
44. or/42-43

## Appendix 2. Search strategy for AMED

1. Anterior cruciate ligament/
2. "Sprains and Strains"/
3. Athletic Injuries/
4. Knee Injuries/
5. Knee/ or Knee Joint/
6. or/2-5
7. (anterior adj3 cruciate\$1).tw.
8. and/6-7
9. or/1,8
10. Exercise/
11. Rehabilitation/
12. Physiotherapy/
13. Exercise therapy/
14. clinical protocols.tw.
15. recovery of function.tw.
16. (physiotherap\$ or physical therap\$ or rehab\$ or training or exercis\$).tw.
17. or/10-16
18. and/9,17
19. randomized controlled trial.pt.
20. controlled clinical trial.pt.
21. Randomized Controlled Trials/
22. Random Allocation/
23. Double-Blind Method/
24. or/19-23
25. Animal/ not Human/

26. 24 not 25
27. clinical trial.pt.
28. exp Clinical Trials/
29. (clinic\$ adj25 trial\$).tw.
30. ((singl\$ or doubl\$ or trebl\$ or tripl\$) adj (mask\$ or blind\$)).tw.
31. Placebos/
32. placebo\$.tw.
33. random\$.tw.
34. Research Design/
35. (latin adj square).tw.
36. or/27-35
37. 36 not 25
38. 37 not 26
39. and/18,26
40. and/18,38
41. or/39-40

### Appendix 3. Search strategy for CINAHL

1. Anterior cruciate ligament/
2. Soft Tissue Injuries/
3. "Sprains and Strains"/
4. Athletic Injuries/
5. Knee Injuries/
6. Knee Joint/
7. or/2-6
8. (anterior adj3 cruciate\$1).tw.
9. and/7-8
10. or/1,9
11. exp Exercise/
12. Rehabilitation/
13. Physical Therapy/
14. exp Therapeutic Exercise/
15. clinical protocols.tw.
16. recovery of function.tw.
17. (physiotherap\$ or physical therap\$ or rehab\$ or training or exercis\$).tw.
18. (rh or th).fs.
19. or/11-18
20. and/10,19
21. exp Clinical Trials/
22. exp Evaluation Research/
23. exp Comparative Studies/
24. exp Crossover Design/
25. clinical trial.pt.
26. or/21-25
27. ((clinical or controlled or comparative or placebo or prospective or randomi#ed) adj3 (trial or study)).tw.
28. (random\$ adj7 (allocat\$ or allot\$ or assign\$ or basis\$ or divid\$ or order\$)).tw.
29. ((singl\$ or doubl\$ or trebl\$ or tripl\$) adj7 (blind\$ or mask\$)).tw.
30. (cross?over\$ or (cross adj1 over\$)).tw.
31. ((allocat\$ or allot\$ or assign\$ or divid\$) adj3 (condition\$ or experiment\$ or intervention\$ or treatment\$ or therap\$ or control\$ or group\$)).tw.
32. or/27-31

- 33. or/26,32
- 34. and/20,33

#### **Appendix 4. Search strategy for EMBASE**

- 1. Anterior Cruciate Ligament Rupture/
- 2. Anterior Cruciate Ligament/
- 3. or/1-2
- 4. Soft Tissue Injury/
- 5. Sport Injury/
- 6. Knee Injury/
- 7. Knee/
- 8. Knee Ligament Injury/
- 9. or/4-8
- 10. (anterior adj3 cruciate\$1).tw.
- 11. and/9-10
- 12. or/3,11
- 13. exp Exercise/
- 14. Rehabilitation/
- 15. Physiotherapy/
- 16. Kinesiotherapy/
- 17. \*Clinical Protocol/
- 18. recovery of function.tw.
- 19. (physiotherap\$ or physical therap\$ or rehab\$ or training or exercis\$).tw.
- 20. or/13-19
- 21. and/12,20
- 22. exp Randomized Controlled trial/
- 23. exp Double Blind Procedure/
- 24. exp Single Blind Procedure/
- 25. exp Crossover Procedure/
- 26. Controlled Study/
- 27. or/22-26
- 28. ((clinical or controlled or comparative or placebo or prospective\$ or randomi#ed) adj3 (trial or study)).tw.
- 29. (random\$ adj7 (allocat\$ or allot\$ or assign\$ or basis\$ or divid\$ or order\$)).tw.
- 30. ((singl\$ or doubl\$ or trebl\$ or tripl\$) adj7 (blind\$ or mask\$)).tw.
- 31. (cross?over\$ or (cross adj1 over\$)).tw.
- 32. ((allocat\$ or allot\$ or assign\$ or divid\$) adj3 (condition\$ or experiment\$ or intervention\$ or treatment\$ or therap\$ or control\$ or group\$)).tw.
- 33. or/28-32
- 34. or/27,33
- 35. limit 34 to human
- 36. and/21,35

## Appendix 5. Search strategy for The Cochrane Library (OVID EBM Reviews)

1. Anterior Cruciate Ligament/
2. Soft Tissue Injuries/
3. "Sprains and Strains"/
4. Athletic Injuries/
5. Knee Injuries/
6. Knee/ or Knee Joint/
7. or/2-6
8. (anterior adj3 cruciate\$1).tw.
9. and/7-8
10. or/1,9
11. Exercise/
12. Rehabilitation/
13. Physical Therapy Techniques/
14. Exercise therapy/
15. \*Clinical Protocols/
16. \*"Recovery of Function"/
17. (physiotherap\$ or physical therap\$ or rehab\$ or training or exercis\$).tw.
18. (rh or th).fs.
19. or/11-18
20. and/10,19

## WHAT'S NEW

Last assessed as up-to-date: 7 June 2005.

8 September 2008	Amended	Converted to new review format.
------------------	---------	---------------------------------

## HISTORY

Protocol first published: Issue 2, 2005

Review first published: Issue 4, 2005

18 May 2006	Amended	In this minor update (published in Issue 3, 2006), format changes were undertaken to comply with the Cochrane Style Guide (May 2006).
24 August 2005	Amended	In a previous comprehensive systematic review (Thomson 2002) the effect of rehabilitation on ACL patients was inconclusive with respect to efficacy of exercise, effectiveness of dosage, setting in which the physiotherapy-led programmes took place and level and type of supervision. That review also limited the trials to physiotherapy-led programmes and did not consider trials when the exercise programmes were prescribed or led by persons other than physiotherapists. That review has now been split and is being updated as a series of separate reviews that includes this current review, and "Exercise for treating isolated meniscal injuries of the knee in adults" (Dixon 2005).

## CONTRIBUTIONS OF AUTHORS

AH Trees, the guarantor for this review, conceived, designed and wrote the protocol, assisted in the development of the search strategy, performed the identification of studies, data extraction, methodological assessment, analysed the results, and wrote and entered the review into RevMan.

TE Howe conceived, designed and wrote the protocol and developed the quality assessment scheme, performed data extraction, methodological assessment, analysed the results and wrote the review.

J Dixon conceived and designed the protocol, and assisted with the search strategy development, identified studies for the review, performed data extraction and commented on drafts of the review.

L White commented on drafts of the protocol and review and assisted in identification of studies for the review.

## DECLARATIONS OF INTEREST

None known.

## SOURCES OF SUPPORT

### Internal sources

- University of Teesside, Middlesbrough, UK.
- Glasgow Caledonian University, UK.

### External sources

- Physiotherapy Research Foundation, UK.

## INDEX TERMS

### Medical Subject Headings (MeSH)

\*Exercise Therapy; Adolescent; Anterior Cruciate Ligament [\*injuries; surgery]; Randomized Controlled Trials as Topic; Recovery of Function

### MeSH check words

Adult; Humans; Middle Aged