Physical Therapy Reviews

ISSN: 1083-3196 (Print) 1743-288X (Online) Journal homepage: https://www.tandfonline.com/loi/yptr20

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To cite this article: E. Dunphy, F. L. Hamilton, K. Button & E. Murray (2020): A scoping review of the resources needed to deliver anterior cruciate ligament physiotherapy rehabilitation in randomised controlled trials, Physical Therapy Reviews, DOI: 10.1080/10833196.2020.1762521

To link to this article: https://doi.org/10.1080/10833196.2020.1762521

Published online: 18 May 2020.

PHYSICAL THERAPY REVIEWS
https://doi.org/10.1080/10833196.2020.1762521

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A scoping review of the resources needed to deliver anterior cruciate ligament physiotherapy rehabilitation in randomised controlled trials

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ABSTRACT

Background: The Anterior Cruciate Ligament (ACL) stabilises the knee and is commonly injured in sport. Surgical repair and rehabilitation are common. However, rehabilitation randomised controlled trials do not always report the resources used to deliver ACL rehabilitation. This may lead to suboptimal availability of resources for evidence based care.

Objective: To identify the resources used to deliver multimodal ACL rehabilitation in randomised controlled trials

Methods: Comprehensive searches, combining 'anterior cruciate ligament', and 'rehabilitation' with the Cochrane RCT filter, were conducted of Medline, Embase, Cinahl, PeDro, Sports Discus and the Cochrane Library. Adults post ACL reconstruction were included. The intervention and comparator were physiotherapy for post-operative rehabilitation. Outcomes were the resources required to deliver rehabilitation, and study type was randomised controlled trials. Papers were screened against the criteria; data were charted and narrative synthesis applied.

Results: Fourteen studies reported on 599 patients. The interventions ranged from 4 to 36 weeks. Physiotherapy was typically an hour and ranged from 1 to 5 sessions/week. Resources included a gym environment with rehabilitation equipment such as resistance machines, free weights, cardiovascular and neuromuscular control equipment, and an experienced physiotherapist.

Conclusions: Implications for future studies include the need for a more detailed report of the resources used in RCTs. Accurate reporting would help healthcare decision makers to effectively manage resources when implementing evidence based care. Findings can be considered as criteria against which to audit resource provision.

KEYWORDS
Anterior cruciate ligament; knee; rehabilitation; health resources; physical therapy modalities

Background

Description of the condition

The anterior cruciate ligament (ACL) is an important stabilising ligament in the knee. Its primary function is to prevent excessive anterior translation of the tibia on the femur in the sagittal plane during dynamic activity [1]. It has a secondary function to resist tibial rotation or when the knee is extended to resist varus and valgus stress in the coronal plane [2]. Injury is common in sport and activities that involve jumping, landing and changing direction [3]. Surgery is the most common management strategy and progression through a phased rehabilitation programme is standard [4, 5]. Recovery is usually measured in terms of a return to previous levels of activity but evidence suggests that only 55% of affected patients, return to competitive sport [6]. There are numerous systematic reviews that demonstrate the most effective physiotherapy interventions [4, 7–10] and rehabilitation should be continued until the patient achieves their functional goals [11]. Hartigan et al. examined the time line for patients to pass a criteria to return to sport [11]. The evidenced criteria included leg symmetry strength testing, a battery of hop tests, and two validated patient rated outcome measures (PROM) [12]. They found that only 5% of patients passed these criteria at three months, 48% passed at six months and 78% passed at 12 months [11]. Criteria for progressing from phase to phase include; early phase: wound closure, minimal effusion, patella mobility, range of motion 0–120, quadriceps control, normal gait and correct performance of phase 2 exercises [4]. Mid phase includes; correct performance of phase 2 exercises, leg symmetry for strength and hopping at 80% and PROM such as the Knee Osteoarthritis Outcome Score (KOOS) [13] and a

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psychological questionnaire [4]. The return to sport criteria include; free of pain and giving way, symmetry of movement in all sport activities, leg symmetry of >90% and repeated PROM [4, 14]. Indeed, 12 months is commonplace for achieving criterion based rehabilitation targets for return to higher level function while it is known that participation in rehabilitation beyond nine months decreases the risk of re-injury [15]. Hence it is clear that rehabilitation after ACL surgery may require substantial investment of time and resources and it is not known what the existing literature says about this.

Description of the problem

An accurate understanding of the resources required for post-operative rehabilitation may help to enable service providers to deliver evidence based care and for commissioners to understand the costs involved. None of the earlier systematic reviews have discussed the resources that are utilised in the RCTs they included, such as exercise equipment or skilled staff required to deliver physiotherapy rehabilitation. Resources required for post-operative rehabilitation as described in RCTs can be considered in three categories: the time and skill of the lead physiotherapist; and the equipment needed. Just as there is a lack of clarity around the equipment needed for the care described in trials, there is uncertainty around the amount of therapist time required to deliver the interventions described. Van Melick et al. noted in a systematic review of evidence based practice for ACL rehabilitation, the lack of high quality studies and contradictory results, which made it difficult to determine the benefits of supervised versus home based rehabilitation [4]. While some studies reported no significant difference they were critiqued for short follow up or unclear population description [16, 17], and other studies reported atrophy and trouble with range of motion leading to 49% of the home based group switching to supervised care [18]. Risberg et al. concluded in a systematic review of evidence for ACL rehabilitation, that rehabilitation must be supervised to some degree by a physiotherapist, though continuous supervision might not be essential, indicating that some populations may manage well independently [8], while Wright et al. concluded "minimally supervised physical therapy in selected motivated patients appears safe" [10].

In the literature there is a paucity of cost data on effective models of ACL rehabilitation. The NHS Economic Evaluation Database (EED) includes one older American study that looks at cost effectiveness comparing two rehabilitation models, the authors impression of typical rehabilitation and his innovative creation, a brace with built in resistance called 'Protonics' [19]. The EED concluded that "the cost data provided in the study are likely to be unreliable and do not provide a true estimate of the implications of introducing a new programme" [20]. Non-UK based surgical studies have included cost for surgery and rehabilitation at $17,000–$25,000 per injury but without a break down of cost [1]. Neither the cost nor the resources needed for models of physiotherapy rehabilitation for ACL rehabilitation are well described in the literature.

Description of the interventions

In the absence of evidence-based guidelines regarding resources required to deliver rehabilitation after ACL surgery, it is necessary to explore alternative sources of evidence to identify the key resource requirements. In this study, we scoped published randomised controlled trials (RCTs) that examined multimodal ACL rehabilitation. The basis for this decision was: RCTs are the "gold standard" for determining effectiveness of treatments. It is not ethical to offer treatment known to be ineffective in a trial. These studies would have examined new or innovative treatments (designed to be an improvement on current effective care) and would have included a comparator arm that reflected current effective care. Moreover, in line with CONSORT reporting guidelines, we anticipated that both the intervention (new practice) and comparator (current practice) would be accurately described, using the TIDieR template [21, 22].

Why it is important to do this review

In the light of known variability in outcomes [6], and variability in the content of rehabilitation provided [23], it is important to gain an understanding of the key resources required to deliver evidence based rehabilitation. This is necessary so that service providers can plan appropriately, and commissioners of care can provide appropriate reimbursement. We wanted our work to be relevant to routine health care providers so we decided to exclude studies focused on elite athletes.

Research Question: What does the available RCT literature tell us about the resources needed to deliver clinic based anterior cruciate ligament reconstruction rehabilitation in terms of equipment, skill or time?

Objectives

The aim of this review was to identify the resources, in terms of equipment and therapist time and skill set, to deliver physiotherapy rehabilitation to adults after ACL reconstruction surgery as described in

randomised controlled trials. The purpose of using a scoping reviews methodology for this study was to map the 'size, range or characteristics' of the resources used in RCTs of ACL rehabilitation [24]. It aimed to identify data that has not been reviewed comprehensively before [25] and to identify gaps in the literature on this subject [24, 26]. Specific objectives were to

- Identify RCTs comparing components of, or approaches to, rehabilitation after ACL reconstruction;
- Extract details of resources such as equipment, time or skill required to deliver the intervention and comparator in these trials;
- Synthesise these findings to provide an overview of the resources required to deliver rehabilitation in RCTs of multimodal ACL rehabilitation

Methods

Scoping reviews share the essential characteristics of other review types, namely, 'collecting, evaluating and presenting the available research evidence' [25]. This review is reported in line with the Arksey and O'Malley framework which aimed to make scoping reviews 'rigorous and transparent' as well as repeatable, to improve methodological rigor [25, 27]. The search was conducted in accordance with Cochrane systematic review methodological guidance in order to ensure a rigorous approach to the gathering of evidence [28]. It was reported with the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist [25]. This review is registered with the Open Science Framework (https://osf.io/a978k).

Criteria for considering studies for this review

The inclusion and exclusion criteria were defined using the Population, Intervention, Comparator, Outcomes, Study type (PICOS) acronym (Table 1).

Search methods for identification of studies

Comprehensive searches were conducted from June to August 2017 of Medline, Embase, Cinahl, PeDro, Sports Discus and the Cochrane Library. There was no limitation on language or year. The strategy consisted of the two concepts: anterior cruciate ligament and rehabilitation. The terms 'anterior cruciate ligament', 'anterior cruciate ligament reconstruction' and 'acl' were searched with truncation, exploded in subject headings and searched as a keyword. For the second concept the words 'rehabilitation', 'exercise therapy', 'physical therapy', 'physiotherapy' 'manual therapy' and 'neuromuscular control' were searched with truncation, exploded in subject headings and keyword searched. Within each concept, terms were combined with Boolean search term "or" and then both concepts were combined with 'and'. Finally the search was limited to randomised controlled trials using the Cochrane RCT filter in Medline, adapting it for Embase, Cinahl and Sports Discus and using inbuilt clinical trials filter in PeDro. Web of science was also searched by the backward and forward citation of 5 key systematic review articles regarding rehabilitation of anterior cruciate ligaments [4, 7–10, 29]. Pilot searches were run to test sensitivity and specificity and no further changes were made (Appendix 1: Search Strategy).

Data collection and analysis

Selection of studies

Titles, abstracts, and full text articles were reviewed by the lead reviewer (ED) and full text articles were reviewed by the lead reviewer (ED) and second reviewer (KB). Translators were used where possible and abstracts in French, Serbian, Italian, Portuguese and Polish were translated for consideration. A dialectic process was followed until agreement on inclusion or exclusion was reached. Authors were contacted for further information as needed. The window for reply was set at four weeks and a follow up email was sent to non-responders after three weeks.

Table 1. PICOS: Population, intervention, comparator, outcomes, study type.

Population	Adults, (aged 16 or over) who were not professional athletes and had undergone ACL reconstruction without complex concomitant injury.
Intervention	Multimodal ACL rehabilitation programmes, including studies of type and timing of exercise interventions, innovative technologies or home versus supervised rehabilitation. Studies were included if they demonstrated effectiveness and if the intervention, the comparator or both included a description of standard ('standard ''usual', 'conventional' or 'traditional') multimodal care such that the details of resources needed could be identified.
Comparator	Standard care or standard care plus a variation, including studies of type and timing of exercise interventions, innovative technologies or levels of supervision.
Outcomes	Resources associated with delivering ACL rehabilitation interventions: Number and length of face-to-face appointments; experience of physiotherapist and equipment required.
Study Type	Randomised Controlled Trials (RCTs) where the primary aim of the study was to evaluate effectiveness of a component(s) of multimodal ACL rehabilitation care.

Data extraction and management

Data were extracted and collated in Excel for 'sifting, charting and sorting' [25]. They were organised by title, author/year/country, description of intervention(s) and comparator(s), number of participants, age, gender, time since injury, type of surgery, intervention length (weeks), primary outcomes and statistical significance. Consultation time, frequency of consultations, location, equipment and experience level of physiotherapist was extracted from descriptions of the comparator. Further data obtained through email contact with corresponding authors were also added. Data were separately reviewed by a second reviewer (KB). Findings were compared and agreed upon (ED & KB).

Critical appraisal of included studies

Critical appraisal of the included studies was done using the Cochrane Collaboration Tool for assessing risk of bias in randomised trials [30]. Risk of Bias usually pertains to a meta-analysis of effectiveness of interventions which was not relevant here but given the included studies were RCTs, it was used a tool of critical appraisal of study quality. Two reviewers separately assessed the studies for each domain (ED & KB).

Data analysis

The data from included studies were summarised and synthesised using a narrative synthesis [31]. This method aims to ascribe meaning based on the textual context rather than the statistical data. It is argued that narrative synthesis allowed this review to focus on the characteristics that shaped the implementation of interventions [31]. The process of narrative synthesis [31] is described in Appendix 2.

Results

Results of the search

References were combined in Endnote and 4277 articles were identified (Figure 1, PRISMA Flowchart). A further group of 351 was identified from Web of

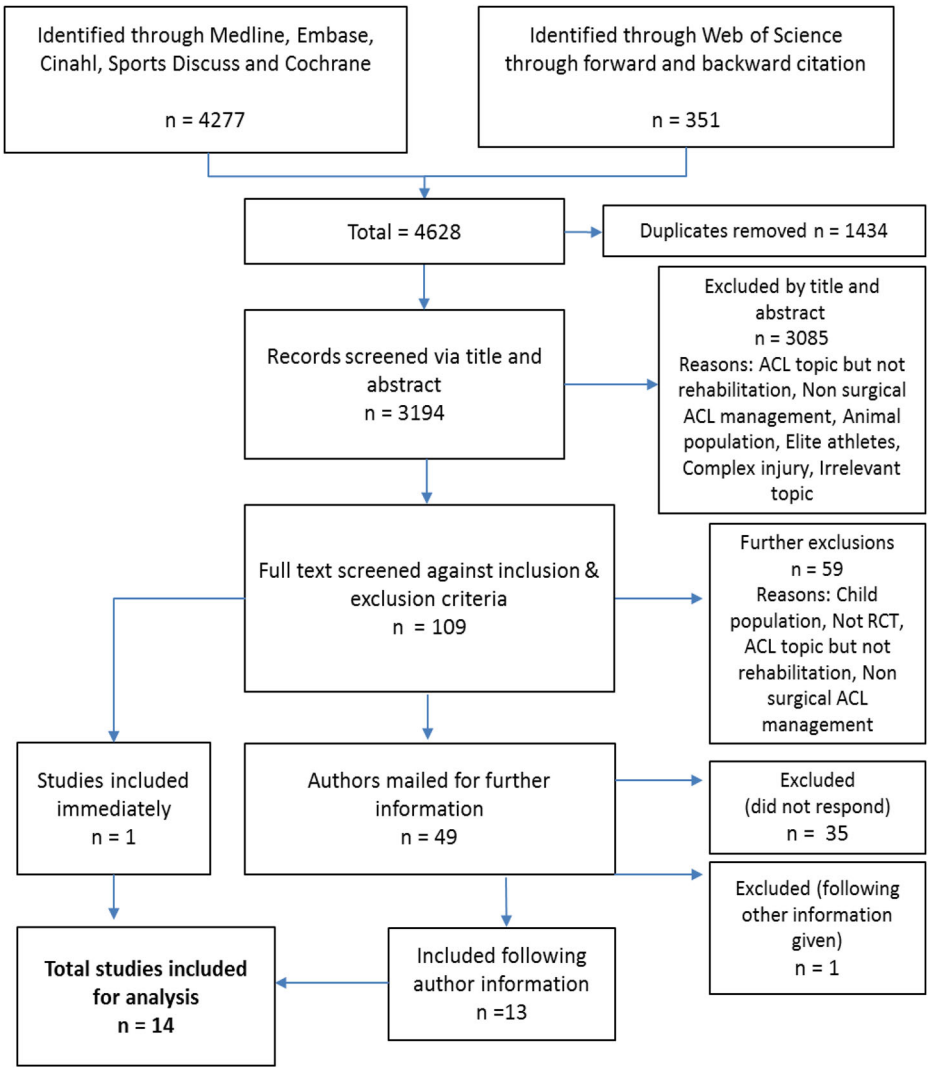

Figure 1. PRISMA Flowchart.

Table 2. Study characteristics phases of rehab: early phase early and middle phases middle phase early middle and late phase.

Author, Year, Country, Citation	Gender	Graft type	Age , Control / Intervention (SD)	Intervention/ Comparator	Length of Intervention	Outcomes Measures	Length of follow up	Results
Chan, 2017, Singapore [37]	46M 14F	HG	27.4 (8.25)/ 26.3 (7.04)	K-tape + standard v. standard care	6 weeks from immediately post operation	Visual Analogue Scale, AROM, Lysolm, Tegner, Patella Circumference	6 weeks	Significant: Visual Analogue Scale *P*=.0164 in the tape group.
Ross, 2000, USA [38]	13M 7F	HG	27.1 ± 4.89 28.4±-5.91	CKC + NMES V CKC	5 weeks, week 1–6	AP Laxity, Unilateral Squat, Lateral step up, Anterior reach	6 weeks	Significant for intervention group: unilateral squat and lateral step *P*=.05
Baltaci, 2013, Turkey [32]	30M	PT	29 ± 7 years / 29 ± 6 years	Wii fit v. standard	12 weeks from immediately post operation	Star excursion balance, Squat test, Muscle testing, Co-ordination, Proprioception, Response time	12 weeks	No significant difference
Kinikli, 2014, Turkey [39]	31M 2F	STG	32.64 ± 8.21 /33.87 ± 8.19	Dedicated eccentric concentric training programme + standard v. standard	15 weeks from immediately post operation	Isokinetic flexors, Isokinetic extensor, Vertical hop, Single Leg Hop for distance, Lysolm Knee scale, ACL-QOL	16 weeks	Significant: vertical hop (*P*=.012), hop for distance (*P*=.027) the Lysolm (*P*=.002) and the ACL-QOL (*P* = 0.00)
Pistone, 2016, Italy [40]	34 NR	HG	27 29	WBVT + standard v standard	12 from week 4 to 16	Isometric strength flexion, Isometric strength extension, Balance, Lysolm	3 months	Significant WBVT: isometric flexion (*P*=.05), balance (*P*=.001 and *P*=.005) and Lysolm score (*P*=.001)
Sekir, 2010, Turkey [41]	48M	PT	24.8 ± 7.2 /25.1 ±- 5.3	Isokinetic hamstrings at 3 weeks + standard v. isokinetic hamstrings at 9 weeks + standard	16 weeks from immediately post operation	Hamstring strength, Quadriceps strength, Cincinnati knee rating scale, IKDC	12 months	Significant: isometric hamstring strength *P* =.007 isokinetic hamstring strength of *P*=.036. The Cincinnati scale of *P*= .024 at 12 months
Cooper, 2005, Australia [42]	20M 9F	26 HG 3PT	31.3(7.8) /24.7(5.1)	Proprioceptive training (PT)v. strength training (ST)	6 weeks from between 4 and 14 weeks onwards	Cincinnati Knee Scale, PSFS, AROM, Hop Tests	6 weeks	Significant for ST: Cincinnati Knee Scale, swelling (*p*=.047), walking (*p*=.04) and squatting/ kneeling (*P*=.01). in activity 2 (*p*=.01) and 3 (*p*=.01) of the PSFS
Moezy, 2008, Iran [43]	23M	BPB	24.51 (3.38) 22.70 (377)	WBVT v standard care	4 weeks from week 13 to 17	Postural Stability, Joint Position Sense	4 months	Significant: in favour of the WBVT group was given a *P*=.05
Bartels, 2016, Germany [44]	14F 36M	HG	31.4 ± 7.48 / 34.4 ± 12.5	Speedcourt system v. standard	4 weeks from week 20 to 24	AROM, Finger Ground Distance, Reaction Time, Ground Contact Time, Tapping, Jump Height 2 and 1 leg, Jump Width, Anthropometry	3 weeks	Significant: improvement in jump height *P*=.02, reaction time *P*=.025 and 3/8 anthropometric measurements.
Christensen, 2013, USA [34]	22M 8F	STG	30.1 ± 10.5y 33.1 ± 10.9y	Early aggressive v non aggressive rehabilitation	24 weeks	AP Laxity, IKDC, AROM, Peak Isometric Force	6 months	No significant difference therefore
Timm, 1997, USA(19)	42M 18F	BPB	25.1 ± 4.3 24.3 ± 2.1	Protonics + standard v standard	24 weeks	Time, Cost	23 weeks	Significant improvement of time and cost *P*=.001 in favour of the Protonics group

(*continued*)

Table 2. Continued.

Author, Year, Country, Citation	Gender	Graft type	Age , Control / Intervention (SD)	Intervention/ Comparator	Length of Intervention	Outcomes Measures	Length of follow up	Results
Moller, 2001, Sweden [33]	30M 32F	BPB	28 (21-53) 31 (19-48)	Bracing + standard v not bracing + standard	28 weeks	Laxity Test, Isokinetic Peak, Single Leg Hop, AROM, Circumference, Lysolm Tegner, VAS	2 years	No significant difference
Heijne, 2007, Sweden [45]	42M 38F	40PT 40 HG	31 (8) 27 (5) 30 (8) 31 (9)	Early start OKC + standard v. Late start OKC + standard in PT and HG	30 weeks from immediately post-operation	AROM, Laxity, Postural Sway, Thigh Muscle, Torque, Anterior Knee Pain score	7 months	Significant increase of graft laxity in the hamstring graft group (4 weeks) P=.04 and P=.02 in two ranges of laxity. significant rotational instability in the pivot shift test in H4 group, P =.04
Hohmann, 2011, Australia [46]	30M 10F	BPB	28 (20–34) 27 (19–35)	Supervised v. unsupervised rehabilitation	36 weeks	Lysolm Tegner, Single Leg Hop Distance, Timed Hop, Vertical Jump, Strength	1 year	Significant: extensor knee strength at 6 months in the supervised group P =.004

Abbreviations: OKC open kinetic chain, CKC closed kinetic chain, NMES neuromuscular electrical stimulation, WBVT whole body vibration training, PT patella tendon, HG hamstring graft, AROM active range of movement, M Male F Female NR Not Reported.

Science and 3194 remained after removal of duplicate references. Of these, 3085 were excluded by title and abstract. The full text of 109 articles was sought. Of these, one study was included and 59 excluded as not meeting inclusion criteria. Of the remaining 49 papers, information about the resources for the intervention or comparator was missing so emails were sent to corresponding authors requesting further information (Appendix 3: Information request letter). Information missing included a description of frequency of appointments, care delivered by whom, in what context and for how long per appointment. Of these, 35 studies had to be excluded as authors did not respond, but the authors of 14 papers responded. One paper was then excluded as it did not meet inclusion criteria, 13 were included based on additional information provided, and therefore 14 studies were included for analysis.

Three included studies did not find the intervention to be more effective than the comparator but were included because the care was still effective in both arms so they met the inclusion criteria of ‘effective’ modes of rehabilitation [32–34]. Christensen et al. and Moller et al. show both arms to be equally effective where patients are seen to be equal to (at two year follow up) [33], or improve relative to (at 24 week follow up) [34], known normative values of the Lysholm, Tegner and International Knee Documentation Committee (IKDC) Score [35, 36]. Comparisons to normative functional data are significantly limited by the 12 week follow for Baltaci et al. who compared to the ‘uninvolved limb’ of the participant at all-time points to illustrate effectiveness [32].

Included studies

The characteristics of the 14 included studies are tabulated in Table 2. A total of 599 patients post ACL reconstruction were included with a range of 20–80 participants per study. There were 413 males, aged from 17 to 46, 152 females and 34 gender unreported. 293 had a hamstring graft and 306 had patella tendon graft. The interventions varied from three weeks to 39 weeks. Some evaluated the early phase [37, 38], middle phase [42–44], early and middle [32, 39–41], where others, were interested in the rehabilitation overall [19, 33, 34, 45, 46].

Critical appraisal

The risk of bias according to the Cochrane tool was high or unclear in many of these studies (Figure 2. Risk of Bias) [30].

Author, Year	Random Sequence Generation: Selection Bias	Allocation Concealment	Blinding participants and personnel: Performance Bias	Blinding of outcome assessment: Detection Bias	Incomplete outcome data: Attrition Bias	Selective reporting: Reporting Bias	Other bias
Chan 2017	☺	☹	?	☹	☹	☺	-
Ross 2000	?	☹	?	?	?	☺	?
Baltaci 2013	☺	?	?	?	?	☺	?
Kinikli 2014	☺	☹	☹	☹	☹	☺	-
Pistone 2016	?	?	?	?	☺	☺	-
Sekir 2010	☹	☹	☹	?	☹	☺	☹
Cooper 2005	☺	☺	?	☺	☺	☺	?
Moezy 2008	?	?	?	?	☹	☺	-
Bartels 2016	☹	?	?	?	☹	☺	☹
Christensen 2013	☺	☹	☹	☹	☺	☺	?
Timm 1997	?	?	☹	?	?	☺	☹
Moller 2001	?	?	☹	?	☹	☺	-
Heijne 2007	☹	?	?	☺	☹	☺	-
Hohmann 2011	☺	☺	☹	☺	☹	☺	?

Figure 2. Risk of Bias – results of individual studies.

Thematic synthesis of results - resources described

Number of sessions per week

The median number of sessions per week was 3, with a range of 1–5 sessions (IQR 1.25–3). The first 6 weeks post-operatively showed the highest number of patient contacts (Table 3). Where the number of sessions varied within studies (i.e. individual patient attendance varied), a mean number of sessions per week was calculated. Studies that ran over a longer period showed a drop off in the number of contacts where weekly physiotherapy reduced to fortnightly and then to monthly. A comparison of the total sessions per complete rehabilitation was not possible due to the varying scope of the included studies.

Number of weeks of intervention

The length of Intervention ranged from 3 weeks to 36 weeks (Table 2) as some studies were of complete rehabilitation programmes [19, 33, 34, 45, 46] whereas others were focused in a phase of rehabilitation [32, 37–44]. In only one study were individuals still receiving treatment beyond 29 weeks (Hohmann et al. [46])

Number of minutes per session

Table 4 shows the number of minutes per session over weeks. It varies between 25 and 104 min with a median length of 60 min (IQR 45:75). Most studies maintained a standard number of minutes throughout the intervention [19, 32–34, 38, 42–44, 46]. Two studies reduced minutes per session over time [41, 45] and two notably gave more time to their intervention group which has implications related to increased use of clinical time [40, 41].

The use of specialist equipment and environment

Table 5 shows that 13 of 14 included studies described the use of specialist equipment for strength exercise as part of standard care. Eight studies used resistance machines such as leg press, leg extensions or leg curls and 10 studies used free weights to add load. Three studies also mentioned Theraband and resistance bands for strengthening while one study used a Slashpipe, for strength and control. Cardiovascular exercise equipment was also standard in 12 of 14 studies. Exercise Bicycles were most common (11/14) with steppers, Nordic tracks and treadmills also mentioned.

Neuromuscular control exercise equipment, for balance, proprioception, agility and plyometrics, was mentioned in 11 out of 14 studies. Trampolines, foam mats, bosu balls, gym balls, wobble boards, tilt boards are mentioned, while other studies affirm neuromuscular exercises but do not provide details. One study mentioned use of tape, 5 used neuromuscular electrical stimulation, and 4 used continuous passive movement (CPM). 4 studies included swimming pool exercises.

Physiotherapist skill level

Table 5 shows 8 out of 14 studies specified that care was delivered by 'experienced physiotherapists', 2 studies only mentioned orthopaedic experience and 3 did not specify. One study also used an athletic trainer alongside the physiotherapist [41]. The term 'experienced' is subjective and no study defined what they meant by experienced. Some research delineates between novice and experienced clinicians but in practice, experience may be qualified in many ways [47].

Table 3. Results of individual studies – Number of sessions per week. Number in each cell represents the number of sessions that week. (Deeper shade of grey in session results associated with more session's per week). Phases of rehab: In grey scale: Early phase Early and Middle phases Middle phase Early middle and Late Phase.

Author, Year (in phase order)	No of sessions p/week w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12	w13	w14	w15	w16	w17	w18	w19	w20	w21	w22	w23	w24	w25	w26	w27	w28	w29	w30	w31	w32	w33	w34	w35	w36
Chan 2017	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ross 2000	5	5	5	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baltaci 2013	3	3	3	3	3	3	3	3	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kinikli 2014	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pistone 2016	0	0	0	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sekir 2010	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cooper 2005	2	2	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moezy 2008	0	0	0	0	0	0	0	0	0	0	0	0	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bartels 2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Christensen 2013	1	1	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Timm 1997	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0
Moller 2001	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	0	0	0	0	0	0	0
Heijne 2007	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	0	0	0	0	0	0	0
Hohmann 2011	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0

Table 4. Results of individual studies – Number of minutes per session over weeks. Number in each cell represents the number of minutes per sessions that week (Deeper shade of grey in minute results associated with longer sessions) Phases of rehab: In grey scale: Early phase Early and Middle phases Middle phase Early middle and Late Phase.

Author, Year (in phase order)	No. of minutes p/session w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12	w13	w14	w15	w16	w17	w18	w19	w20	w21	w22	w23	w24	w25	w26	w27	w28	w29	w30	w31	w32	w33	w34	w35	w36
Chan 2017	37.5	37.5	37.5	37.5	37.5	37.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ross 2000	30	30	30	30	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baltaci 2013	60	60	60	60	60	60	60	60	60	60	60	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kinikli 2014	20	20	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pistone 2016	0	0	0	96	100	104	100	90	90	90	90	90	90	90	90	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sekir 2010	50	50	53	53	53	53	48	48	53	53	53	40	40	40	40	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cooper 2005	50	50	50	50	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moezy 2008	0	0	0	0	0	0	0	0	0	0	0	0	60	60	60	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bartels 2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	45	45	45	0	0	0	0	0	0	0	0	0	0	0	0	0
Christensen 2013	75	75	0	75	0	0	0	75	0	0	0	75	0	0	0	75	0	0	0	75	0	0	0	75	0	0	0	0	0	0	0	0	0	0	0	0
Timm 1997	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	0	0	0	0	0	0	0	0	0	0	0	0
Moller 2001	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	0	0	0	0	0	0	0	0
Heijne 2007	60	60	60	60	60	60	60	60	60	60	60	60	25	25	25	25	25	25	25	25	25	25	25	25	0	0	0	0	0	0	0	0	0	0	0	0
Hohmann 2011	60	60	60	60	60	60	60	0	60	0	60	0	60	0	60	0	60	0	60	0	60	0	60	0	60	0	0	0	60	0	0	0	60	0	0	0

Table 5. Results of individual studies – resources used in descriptions of standard care in either intervention or comparator arms of included studies. Phases of rehab: In grey scale: Early phase Early and Middle phases Middle phase Early middle and Late Phase.

Author, Year, Country, Citation	Clinician Type	Strength: Resistance Machines	Cardio	Neuromusclar Control	Other
Chan, 2017, Singapore	Sports physiotherapists with advanced qualifications	Strength no detail	Cardio No detail	'Neuromusclar Control' no detail	Neuromuscular Electrical Stimulation
Ross, 2000, USA	Not specified	Free Weights	Bicycle, Treadmill, stairclimber		
Baltaci, 2013, Turkey	Physical therapists	Resistance Machine Knee Exercises	Bicycle	Balance boards,	
Kinikli, 2014, Turkey	Experienced Physiotherapist	Leg Press, Free Weights, Theraband, Resistance Band	Bicycle	Balance boards, cushions, Step, Ball	
Pistone, 2016, Italy	Experienced physiotherapists	Leg Press, Leg Curl, Leg Extension, Free Weights	Bicycle	Step, trampoline, 'balance and proprioception' details unclear	Pool, Neuromuscular Electrical Stimulation, Continuous Passive Movement
Sekir, 2010, Turkey	Experienced physiotherapists & Athletic Trainer	Leg Press	Bicycle, Stair machine, Treadmill	Foam Mat, Wobble Board, Step, Cones	Neuromuscular Electrical Stimulation, Continuous Passive Movement
Cooper, 2005, Australia	Experienced physiotherapists	Free Weights, Theraband, Resistance Band	Bicycle	Wobble boards, mini-trampolines, air cushions, gym balls, Step	
Moezy, 2008, Iran	Not specified	Leg Press, Leg Curl, Free Weights		Tilt Board	
Bartels, 2016, Germany	Surgeons only mentioned	Slashpipe	Stepper	Posturomed, Gym ball, BOSU, Foam Mat, Wobble Board	
Christensen, 2013, USA	Experienced physiotherapists	Free Weights	Bicycle	Neuromusclar Control and plyometric, staged. assorted (unclear)	Pool Continuous Passive Movement
Timm, 1997, USA	Experienced physiotherapist	Leg Press, Free Weights	Bicycle, Stair Master, Nordic Track	Proprioception (unclear), step,	Pool
Moller, 2001, Sweden	Surgeons only mentioned	Leg press, Leg Extension, Free Weights	Bicycle	Proprioceptive training (unclear), plyometric (unclear) step,	
Heijne, 2007, Sweden	Experienced physiotherapists	Leg Press, Leg Curl, Free Weights	Bicycle, Stair Machine, Treadmill	Step, trampoline, slide board, balance boards	
Hohmann, 2011, Australia	Not specified	Free Weights	Bicycle that Measures Watts		Pool

Discussion

Summary of main results

The aim of this review was to provide an analysis of the resources used to deliver effective physiotherapy rehabilitation as reported in RCTs. Fourteen RCTs of ACL rehabilitation that included or made available a description of the resources of the intervention were included. Overall, reporting of exercise interventions or resources used was scanty. This makes it hard for other researchers to replicate findings or for health care professionals to implement them. The key findings of this review are that ACL rehabilitation in RCTs is most often delivered by an experienced physiotherapist, requires access to a gym and use of specialist equipment, including resistance machines, free weight and neuromuscular control equipment. All studies reported use of strength equipment however use of resistance machines did not occur in early phase studies. Cardiovascular exercise equipment was used stages of care as was neuromuscular control in most cases. Some exercise plans were not as well reported as others for detailed examination. These types of physiotherapy equipment is not routinely found in homes and suggests the need for gym access in the clinical environment or community; that includes guidance with specialist rehabilitation equipment. Clinical audits of evidence based ACL rehabilitation services should include an analysis of availability of these resources based on the findings of this review.

It was also clear that substantial therapist time was required for many interventions. The median time per contact was 60 min with a median number of 3 sessions per week. Contacts appeared to be shorter in the early phase interventions than other phases but number of contacts per week did not appear to be related to the phase of the study. Some

studies that lasted for longer periods showing a progressive reduction in the number of contacts, perhaps reflecting a greater emphasis on patient independence as the RCT treatment progressed in keeping with principles of supported self-management [48].

The synthesis of resource use also highlighted that the majority of studies associated with 3 or more rehabilitation sessions per week were also the studies investigating use of high-cost, specialised equipment such as the whole body vibration training (WBVT), isokinetic machines, NMES, Protonics and Nintendo Wii [19, 32, 33, 38–41, 43, 44]. These studies notably consumed higher levels of resource compared with studies reporting 2 or fewer appointments per week, which investigated exercise interventions or tape and may be considered more low cost interventions [34, 37, 42, 44–46].

The implications of this study for designing future ACL rehabilitation research are that where complex interactions of exercise and other modalities are tested, reporting of resources as part of scientific method would be beneficial. This could aid health managers to make decisions that weigh resource use and effectiveness.

Within the context of existing literature

Previous systematic reviews have looked at the effectiveness of interventions such as open and closed chain exercises on strength [4, 7, 8], the relationship of strength and neuromuscular control exercises on function [4, 8], the effectiveness of neuromuscular electrical stimulation in the early post-operative phase [4, 8, 9], bracing post operatively and CPM [7, 10, 29] and comparing supervised rehabilitation compared and unsupervised rehabilitation [4, 8, 10]. This review has identified a similar group of studies while also capturing more novel approaches to rehabilitation including the Wii fit, WBVT, Protonics and Speedcourt systems which represented investigations of technological innovations for use in rehabilitation [19, 32, 43, 44].

This scoping review adds to the available literature on ACL rehabilitation. It contributes the knowledge that key factors such as physiotherapist time, skill level and resources should be reported clearly in RCTs in order to facilitate cost planning and reproducibility of findings. We also contribute the new findings that specialist equipment and the oversight of an experienced physiotherapist are commonly used in RCTs to contribute to effective ACL rehabilitation.

Strengths and limitations

This review was conducted in a rigorous fashion, following Cochrane guidance. The PRISMA-ScR checklist is included to demonstrate exhaustive reporting of process. Our searches identified a similar body of work to previous reviews in this area, providing reassurance that they were adequately sensitive, and no key studies were missed. The narrative synthesis was appropriately applied to explore factors beyond effectiveness and highlight the resources characteristics of some RCTs that show effective rehabilitation have higher resource use implications than others. However, of the 49 studies meeting the inclusion criteria, only 14 could be included in the review due to incomplete reporting of the intervention in line with TIDier principles [22]. It was unfortunate that more authors of primary studies did not respond to our request for further information. Limiting our inclusion criteria to randomised controlled trials may have excluded some studies that provided more information about the intervention content.

Implications

Implications for clinical practice include the knowledge that ACL rehabilitation RCTs describe rehabilitation that requires a gym environment with specialist rehabilitation equipment and oversight of an experienced physiotherapist, however 'experience' cannot be defined from these studies. Clinical audits should include a review of these factors to establish ability to implement the research. Services that are unable to provide this should consider advising patients on how to access these resources elsewhere. Although no conclusions can be drawn about therapist time as a resource, the average of 3 supervised sessions per week seems high and carries a cost burden. Implications for future studies include the need for a more detailed report of the resources used in clinic. Reporting of these details would help healthcare decision makers to effectively manage resources when delivering evidence based care.

Acknowledgments

The lead author was (in part) supported by the National Institute for Health Research (NIHR) Collaboration for Leadership in Applied Health Research and Care (CLAHRC) North Thames at Bart's Health NHS Trust. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health and Social Care.

Funding

This study/project is funded by the National Institute for Health Research (NIHR) Clinical Doctoral Research Fellow programme(ICA-CDRF-2016-02-027). The views expressed are those of the author(s) and not necessarily

those of the NIHR or the Department of Health and Social Care.

Disclosure statement

No potential conflict of interest was reported by the authors.

Ethical statement

N/A.

Funding

This study/project is funded by the National Institute for Health Research (NIHR) Clinical Doctoral Research Fellow programme(ICA-CDRF-2016-02-027). The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care.

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Appendix 1: Search strategy

Database: Ovid MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) <1946 to Present>

Search Strategy:

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1 exp Anterior Cruciate Ligament Reconstruction/ or exp Knee Joint/ or exp Anterior Cruciate Ligament/ or anterior cruciate ligament*.mp. (65018)

2 physical therapy modalities/ or exercise therapy/ or muscle stretching exercises/ or plyometric exercise/ or resistance training/ or musculoskeletal manipulations/ or massage/ or rehabilitation/ (93370)

3 physiotherapy.mp. (15504)

4 physiotherap*.mp. (20990)

5 rehabilitation.mp. or exp Rehabilitation/ (365224)

6 manual therapy.mp. or Musculoskeletal Manipulations/ (2711)

7 electrotherapy.mp. (1968)

8 exercise therapy.mp. or exp Exercise Therapy/ (41962)

9 exercise therap*.mp. (34910)

10 neuromuscular control.mp. (1046)

11 acl.mp. (13325)

12 manual therap*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1965)

13 exercise therap*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (34910)

14 1 or 11 (68333)

15 5 and 14 (6185)

16 Anterior Cruciate Ligament Injuries/ (8034)

7 1 or 16 (65018)

18 2 or 3 or 4 or 5 or 6 or 8 or 9 or 10 or 12 or 13 (376918)

19 17 and 18 (6491)

20 1 or 11 or 16 (68333)

21 18 and 20 (6576)

22 randomized controlled trial.pt. (462115)

23 controlled clinical trial.pt. (94040)

24 randomized.ab. (403274)

25 placebo.ab. (188761)

26 drug therapy.fs. (1991821)

27 randomly.ab. (280150)

28 trial.ab. (422286)

29 groups.ab. (1725818)

30 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 (4099198)

31 exp animals/ not humans.sh. (4396754)

32 30 not 31 (3544583)

33 21 and 32 (2032)

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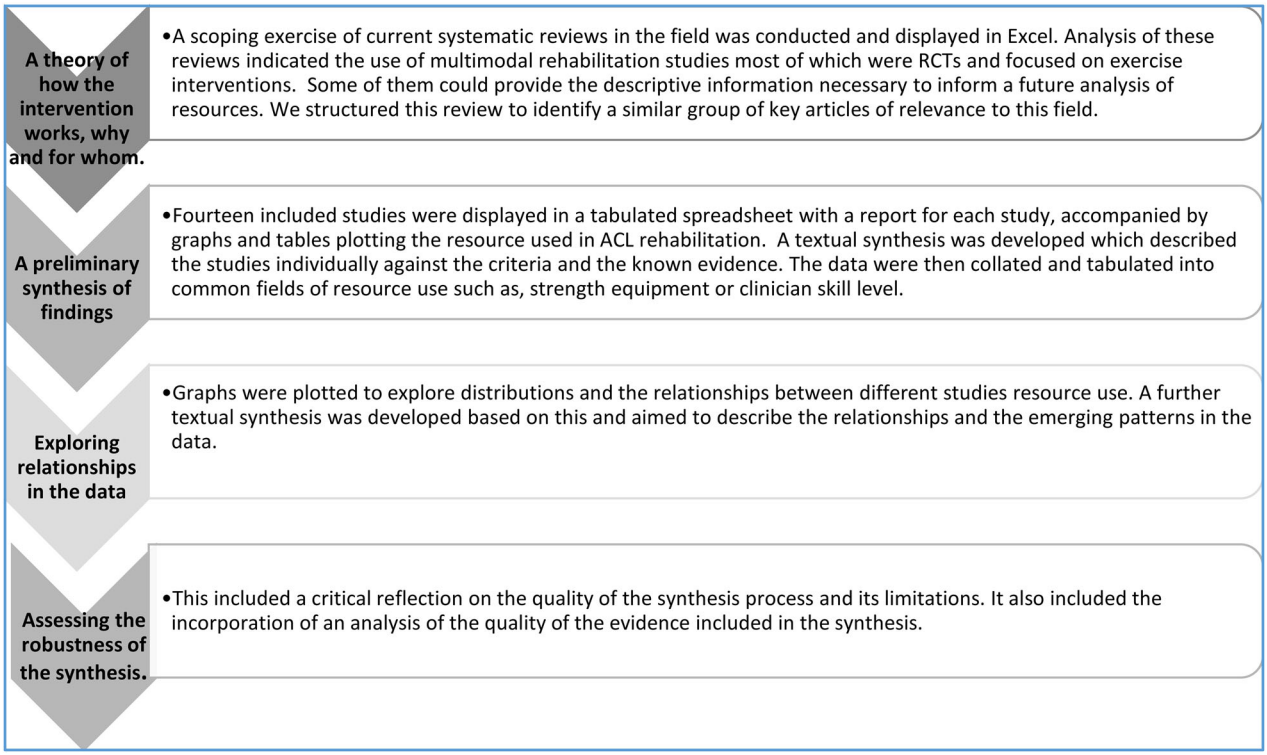
Appendix 2: Process of narrative synthesis



Appendix 3: Information request letter

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