The Influence, Barriers to and Facilitators of Anterior Cruciate Ligament Rehabilitation Adherence and Participation: a Scoping Review

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Abstract

Background: Outcomes following anterior cruciate ligament (ACL) reconstruction are considered poor. There are many factors which may influence patient outcomes. As such, the purpose of this review was to report on the influence, barriers to and facilitators of rehabilitation adherence and participation after ACL reconstruction, providing information to help clinicians and patients make quality decisions to facilitate successful rehabilitation.

Methods: A systematic search of five electronic databases was undertaken in identifying studies from inception to 18 July 2019. The search included English language articles reporting on the influence, barriers to and facilitators of adherence and participation in rehabilitation of patients who have undergone ACL reconstruction. Data extraction and synthesis of included studies were undertaken.

Results: Full text articles (n = 180) were assessed for eligibility following screening of titles and abstracts (n = 1967), yielding 71 studies for inclusion. Forty-four articles investigated ‘rehabilitation prescription and participation’ and 36 articles investigated ‘rehabilitation barriers and facilitators’. The results indicate that a moderately or minimally supervised rehabilitation program is at least as effective as a fully supervised high-frequency rehabilitation program, although a longer duration of supervised rehabilitation is associated with improvement in a multitude of functional outcomes. A number of psychological factors associated with rehabilitation adherence were also identified. The most commonly investigated concepts were self-motivation, athletic identity and social support. Patients perceived the therapeutic relationship, interaction with family and friends, self-motivation, fear of reinjury, organisation/lack of time and interpersonal comparison as the most common barriers to and facilitators of rehabilitation.

Conclusions: A longer duration of supervised rehabilitation is associated with an increased chance of meeting functional and return to sport criteria; however, the optimal supervised rehabilitation frequency is yet to be determined. Identification of the barriers to and facilitators of adherence and participation in ACL rehabilitation provides an opportunity for further research to be conducted to address personal, environmental and treatment-related factors, with the aim to improve rehabilitation outcomes.

Keywords: Anterior cruciate ligament, Physiotherapy, Return to sport, Adherence, Compliance, Rehabilitation

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Key Points

- A longer duration of supervised rehabilitation is associated with more favourable post-operative outcomes.
- The optimal frequency of supervised post-operative rehabilitation is unknown.
- Patients experience a variety of psychological, environmental, personal and treatment-related barriers to and facilitators of rehabilitation.

Background

Anterior cruciate ligament (ACL) injury occurs during rapid valgus loading and internal tibial rotation of the knee [1]. Every year, 3% of amateur athletes injure their ACL, often requiring subsequent reconstruction [2]. Injury of the ACL is also one of the most devastating, resulting in significant time loss from sport [2], long-term functional knee impairments [3], reduced quality of life [4], financial burden [5] and early-onset osteoarthritis [6].

Despite significant advances in surgical technique, the outcomes following ACL reconstruction continue to be reported as poor [7]. Research demonstrates that only 55% of patients who undergo ACL reconstruction make a return to competitive sport [8], and between 15 and 23% of young athletes will suffer a re-rupture or injure the contralateral knee [9]. Reinjury rates are even higher for those under 18 at 33% [10].

Potentially, the underutilisation of rehabilitation in recovery from ACL injury is contributing to the poor outcomes [11]. Growing evidence suggests that due to inadequacies in current rehabilitation programs, patients return to sport (RTS) too early and with significant deficits in knee function, risking reinjury and long-term impairments [12]. There has been substantial research attempting to formulate an evidence base of what best practice ACL rehabilitation programs should include [13]. Despite this, Van Melick et al. (2016) highlighted the current lack of evidence regarding the optimal rehabilitation period or how many appointments work best for RTS [14]. Furthermore, it appears warranted to consider the contextual and personal factors of rehabilitation programs that may act as barriers to or facilitators of rehabilitation. Increased awareness and understanding of these factors may offer new insights and opportunities to improve long-term ACL reconstruction outcomes and enhance clinicians’ ability to provide patient-centred care [15].

Clinicians are therefore continuing to seek guidance on the best way to structure and deliver rehabilitation to facilitate return to sport and minimise the risk of reinjury. With that in mind, this scoping review aims:

- To report on the influence of rehabilitation adherence and participation on outcomes after ACL reconstruction
- To report on the barriers to and facilitators of adherence and participation in ACL rehabilitation
- To provide information to help clinicians and patients make quality decisions to facilitate adherence and appropriate participation in ACL rehabilitation

Methods

A scoping review was conducted to synthesise evidence on ACL reconstruction rehabilitation adherence and participation for the clinician providing rehabilitation services to patients who have undergone ACL reconstruction. Due to the broad exploratory nature of the topic, a scoping review design and methodology was used to facilitate collation and mapping of evidence for the identification of key concepts, knowledge gaps and the types of evidence currently available [16].

Research Questions

The research questions are:

1. What is the reported influence of adherence and participation in ACL reconstruction rehabilitation on patient outcomes?
2. Which factors are reported to influence adherence and participation in ACL reconstruction rehabilitation?

Protocol

A single researcher (AW) conducted the literature search to identify, screen and select studies to be included in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis Extension for Scoping Reviews (PRISMA-ScR) [17]. An a priori protocol was developed and published on the Open Science Framework (https://osf.io/a7tz8/?view_only=9bc5d21c0c034f70a37202abab7330c0) prior to data extraction, on the 10 August 2019. No changes were made to the protocol from publication through to completion.

Study Design

The search strategy was developed through the application of the methodological frameworks proposed by Arksey and O’Malley (2005) [16] and Peters et al. (2015) [18]. We followed a 3-step approach:

1. A pilot search of PubMed and Embase using the medical subject headings ‘anterior cruciate ligament’ AND reconstruction AND rehabilitation AND ‘patient compliance’ (May 2019).
2. Identified keywords and terms relating to anterior cruciate ligament reconstruction rehabilitation adherence and participation (May 2019).
3. Execution of the final search strategy and further searching of reference lists of the selected articles, systematic reviews and narrative reviews (July 2019).

A search was formulated (supplementary file 1) and conducted in 5 databases (PubMed, Embase, CINAHL, SPORTDiscus and Web of Science) from inception to 18 July 2019. Articles were downloaded to the EndNote reference management software (https://www.endnote.com/) for selection by AW according to the PRISMA-ScR statement [17] (Fig. 1).

Eligibility criteria
The eligibility criteria were defined by the Population (any individual that had undergone an anterior cruciate ligament reconstruction regardless of graft type or concomitant injury), Concept (any study reporting on the effect of adherence and participation in rehabilitation or a rehabilitation program) and Context (all periods of time, outcomes, comparators, follow up, rehabilitation setting and duration and type of intervention). The following types of publications were eligible for inclusion: original research, reviews, scoping reviews, systematic reviews, meta-analysis, case series and clinical commentaries.

Exclusion criteria were (a) non-English language, (b) examined pre-operative interventions or non-operative rehabilitation intervention for ACL rupture and (c) no access to the full text. The following were also excluded from our review: conference abstracts/proceedings, opinion pieces, guidelines, magazine and newspaper articles and rehabilitation protocols.

Data extraction
AW extracted data from publications meeting inclusion criteria into a custom Excel spreadsheet. Data extraction, categorisation and mapping were performed as per Peters et al. (2015) in an iterative process as the reviewer became more familiar with the evidence [18].

Synthesis and risk of bias
To answer the research questions, data were narratively synthesised by the author-defined categories: (A) rehabilitation prescription and participation and (B) barriers to and facilitators of rehabilitation. Studies in category A were further categorised into 3 sub-categories: ‘supervised rehabilitation frequency’, ‘supervised rehabilitation duration’ and ‘rehabilitation adherence’. Studies in category B were further categorised into three sub-categories: ‘psychological’, ‘patient...
perspectives’ and ‘other factors’. Studies may be allocated to multiple groups. Results were mapped based on the population profile (age, sex, activity level), study design and concepts investigated. The synthesis of qualitative data was guided by the methodological framework presented by Thomas and Harden (2008) [19]. In line with the recommended scoping review methodology, a quality appraisal is not required [16, 18].

Results
The search strategy yielded 4532 citations with two additional records added following reference list searching [20, 21]. Duplicates (n = 2385) were removed, and exclusion based on screening of title and abstract (n = 1967) left 180 full-text articles which were retrieved and assessed for eligibility. Of these, 111 were excluded for the following reasons: 85 studies did not investigate or have outcomes related to either adherence or participation in rehabilitation; nine were of non-English language; 12 had no access to full text; four were opinion, editorial or news articles; and one article with a non-pure ACL data set (participants from multiple injuries). Seventy-one publications fulfilled the criteria and were included in the review (Fig. 1).

The 71 included articles included 19 reviews and 52 studies. The articles were categorised as per Table 1, with four reviews [13, 58–60] and five studies [30, 61, 62, 70, 71] classified in multiple categories. As outlined in the synthesis and risk of bias methods section, the articles in category (A) were selected to answer the first research question: What is the reported influence of adherence and participation in ACL reconstruction rehabilitation on patient outcomes? Forty-four articles consisting of 12 reviews and 32 original studies were included in this category. An article was categorised into ‘supervised rehabilitation frequency’ if it investigated the difference in outcomes between varying rates of attendance to a rehabilitation service. Most of these articles were developed to investigate home versus clinic-based rehabilitation. An article was categorised as ‘supervised rehabilitation duration’ if it investigated the association between a shorter versus longer duration of supervised rehabilitation on outcome and an article was categorised as ‘rehabilitation adherence’ if it utilised an adherence measure to determine the correlation between adherence to a prescribed rehabilitation protocol and outcome.

The articles in category (B) were selected to answer the second research question: Which factors are reported to influence adherence and participation in ACL reconstruction rehabilitation? Thirty-six articles consisting of 10 reviews and 26 original studies were included in this category. An article was categorised into ‘psychological’ if it investigated the association between a psychological variable and adherence to rehabilitation, as ‘patient perspectives’ if the study included a qualitative research methodology reporting on patients’ opinions and perspectives on barriers to and facilitators of rehabilitation and as ‘other factors’ if it did not fit the first two categories.

Publication dates varied from 1997 to 2019. The number of articles published increased substantially from 2015 (Fig. 2), illustrating the rise in interest in the topic.

Category (A) Rehabilitation Prescription and Participation

| Supervised Rehabilitation Frequency | Reviews | References |
|-------------------------------------|---------|------------|
| Supervised rehabilitation frequency | 9       | [13, 22–29] |
| Supervised rehabilitation duration  | 0       | [58–60]    |
| Rehabilitation adherence            | 3       | [50–57]    |

Category (B) Rehabilitation Barriers and Facilitators

| Psychological | Reviews | References |
|---------------|---------|------------|
| Patient perspectives | 10      | [13, 21, 58–60, 65–69] |
| Other factors   | 0       | [30, 70, 87] |

| Psychological | Reviews | References |
|---------------|---------|------------|
| Patient perspectives | 10      | [13, 21, 58–60, 65–69] |
| Other factors   | 0       | [30, 70, 87] |
in design, seven randomised controlled trials (RCT), three prospective, one cross-sectional and one case report (Table 3). The mean age was 27.6 (21.4–35.5). All but one study had male and female participants. Thirteen studies utilised the bone-patella tendon-bone (BPTB) graft, ten hamstring graft, two allografts and one did not state. Participant activity level was not stated in 13 studies, while athletes of various levels were involved in seven studies.

A variety of outcome measures (OMs) were used (Table 3) with no single OMs used consistently across the majority of studies. Outcome measure use was investigated by grouping the type of OM into the following categories: hop tests, isokinetic dynamometry, patient reported OMs, clinical-based OMs and other OMs. The number of studies in each category were as follows; five studies used at least one hop test [30, 33, 36, 40, 46], eight studies used an isokinetic dynamometry strength measure [30, 31, 34, 37, 38, 40, 42, 45] and 18 different patient-reported OMs were utilised in 12 different studies [30, 32–39, 43, 44, 46]. Eighteen different clinical-based assessments (pain, range of motion, atrophy, effusion, laxity, Lysholm knee score, Tegner activity scale and international knee documentation committee knee evaluation) were used in 15 studies [31–38, 40, 43–48] and 14 other OMs (RTS status/activity level, re-rupture, gait analysis, functional movement screen, surgery satisfaction, imaging and demographics) were utilised in 10 studies [38, 39, 41–44, 46–49].

Table 2 Summary of included reviews investigating ‘supervised rehabilitation frequency’

| Author (year)       | Review type | Dates       | Methodological quality                      | No. included original studies | Conclusion       |
|---------------------|-------------|-------------|---------------------------------------------|------------------------------|-----------------|
| Anderson et al. (2016) [13] | Systematic  | 2004-14     | Not assessed                               | 4                            | Inconclusive    |
| Andersson et al. (2009) [22] | Systematic  | 1995-2009   | Severely limited by methodology quality     | 7                            | Inconclusive    |
| Coppola and Collins (2009) [23] | Systematic  | 1980-2007   | Moderate quality                           | 3                            | Inconclusive    |
| Kruse et al. (2012) [24] | Systematic  | 2006-10     | Large biases in studies                    | 6                            | Equally effective |
| Lobb et al. (2012) [29] | Non-systematic | Until 2011 | Moderate evidence                          | 2                            | Equally effective |
| Papalia et al. (2013) [25] | Systematic  | Until 2013  | Good quality                               | 10                           | Equally effective |
| Risberg et al. (2004) [26] | Systematic  | Until 2003  | Significant limitations across studies      | 3                            | Equally effective |
| Trees et al. (2005) [27] | Systematic  | Until 2005  | Poor                                       | 3                            | Equally effective |
| Wright et al. (2008) [28] | Systematic  | Until 2005  | Biases present                             | 4                            | Equally effective |

Methodological quality refers to the outcome of the quality appraisal undertaken by the review not the authors of this study. The conclusion stated is that of the included review in reference to the comparison of home versus clinic-based rehabilitation. The number of original studies is only those included in each review for the evaluation of home versus supervised rehabilitation.
| Author (year) | Design | Population | Groups: av no. appointments (av/week) | Supervision category | Intervention period (months) | OM assessment (months) | OM assessment | OMs |
|--------------|--------|------------|--------------------------------------|----------------------|-----------------------------|-----------------------|--------------|-----|
| Beard and Dodd (1998) [31] | RCT    | 31 28 M 21 F 5 BPTB | Not stated | Home not specified Clinic + knee class: 16 (1.33) | High | Unspecified | Pre-operative, 3 and 6 | Lysholm knee score, IKDC knee evaluation form, Modified Tegner activity score, VAS sports frequency and level, VAS ADLs, Isokinetic Fl and ext (60deg/sec), KT-1000 |
| Christensen et al. (2018) [32] | Retrospective 332 31.2 M 192 F HS / BPTB | Not stated | Unsupervised: 3–7 (0.16) Semi-supervised: 8–13 (0.33) Supervised: 14–35 (0.76) | Low | Late (0-8) | 8 | KOS-ADL, NPRS |
| Darian et al. (2015) [33] | Case report 1 22 M HS Competitive sport | Supervised: 15 (0.63) | High | At physician clearance (6.3) | Isokinetic ext (60deg/sec), isometric ext (90deg), single hop for distance, IKDC 2000 subjective knee evaluation, physical therapy questionnaire |
| De Carlo and Sell (1997) [34] | Retrospective 180 26.8 M 130 F 50 BPTB | Sport participation (100%) | Home: 7 (0.29) Standard routine: 20 (0.83) | Low | Mid (0-6) | 1.6 and 12 | Isokinetic Fl and ext (180deg/sec), ROM, Modified Noyes Questionnaire |
| Dempsey et al. (2019) [30] | Cross-sectional 60 29.7 M 31 F HS/ BPTB | Competitive (57%) Recreational (41%) Non-athletes (3%) | Cohort: 58.2 (224) | High | Mid (av. 6.3) | | |
| Feller et al. (2004) [35] | Retrospective 20 28 M 16 F 4 HS/ BPTB | Not stated | Minimal: 0–3 (0.04) Intermediate: 4–11 (0.14) Regular: 15–50 (0.51) | Low | Late (0–12) | 12 | Cincinnati knee score, Cincinnati occupational rating scale, Cincinnati sports activity level, IKDC knee evaluation form, KT-1000 |
| Fischer at al. (1998) [36] | Prospective 54 30.5 M 28 F 26 BPTB/ allograft | Not stated | Home: 5 (0.21) Clinic: 19.9 (0.83) | Low | Mid (0–6) | Examination at 1 week, 1.5, 3, 4.5 and 6 Lysholm at 3 and 6 Hops and HSQ at 6 | Lysholm knee score, HSQ, ROM, KT-1000, Effusion, PF J crepitus, anterior draw, medial-lateral laxity, posterior draw, Lachman’s, pivot shift, thigh atrophy, single hop for distance, 6m timed hop, triple hop for distance, triple crossover hop for distance |
| Grant and Mohtadi (2005) [37] | RCT 145 29.3 M 85 F 60 | Not stated | Home: 3 (0.25) Clinic: 14 (1.17) | Mod | Early (0–3) | Pre-operative, 1.5 and 3 | ACL-QoL questionnaire, ROM, KT-2000, knee ROM in gait, isokinetic Fl and ext (180deg/sec) |
| Grant et al. (2010) [38] | RCT 88 33.7 M 58% F 42% | Not stated | Home: 3 (0.25) Clinic: 14 (1.17) | Mod | Early (0–3) | 26-53 | ACL-QoL, ROM, KT-1000, IKDC knee evaluation form, isokinetic Fl and ext (60deg/sec) |
| Han et al. (2015) [39] | Retrospective 93 23 M 82 F 11 HS Recreational athletes | Non-compliant: 3.6 (0.1) Mod compliant: 10.7 (0.3) Fully compliant: 17 (0.47) | Low | Late (0–9) | Pre-operative | Self-report RTS, Cincinnati sport activity level, Lysholm knee score, KOOS, SF-36, PCS, MCS |
Table 3 Summary of included original studies investigating ‘supervised rehabilitation frequency’ (Continued)

| Author (year) | Design | Population | Groups: av no. appointments (av/week) | Supervision category | Intervention period (months) | OM assessment (months) | OMs |
|---------------|--------|------------|--------------------------------------|----------------------|-----------------------------|------------------------|-----|
| Hohmann et al. (2011) [46] | RCT    | 40         | M 20 F 20 BPTB Physically active     | Low                   | Late (0–12)                 | 1.5, 3, 6, 9 and 12   | Lysholm knee score, Tegner activity level scale, single hop for distance 6 m timed hop, vertical jump, isokinetic F and ext (120deg/sec), isometric ext (30deg) |
| Inacio et al. (2016) [41] | Retrospective | 6385      | M 4657 F 1728 HS/ BPTB/ allograft Not stated | Medical encounters in days 1–90 and 91–180 | N/A               | Mid (0–6)       | Mean 28 ± 1.8 years Revisions within 6 months |
| Lim et al. (2019) [42]  | Prospective | 26        | M 18 F 8 HS Not stated              | Low                   | Mid (0–6) | Pre-operative and 6 | Isokinetic F and ext (60deg/sec and 180 deg/sec), Biodex stability system SD OSL |
| Miller et al. (2017) [43] | Retrospective | 660       | M 389 F 271 Not stated              | Minimal: < 9 Moderate: 9–14 High: > 15 Unable to determine Mid (3+) | Admission and last formal PT visit | KOS-ADL, NPRS, age, sex, intervention charges, ACL revision rate, area deprivation index, payer mix |
| Przybylak et al. (2018) [44] | Prospective | 50        | M 37 F 13 HS/ BPTB Recreational athletes | Home 6 (0.12) Supervised: 48 (0.92) | Low                   | Late (0–12) | Pre-operative and 12 | Kuja’s Scoring questionnaire, Tegner activity scale, KOOS, ROM, FMS |
| Revenas et al. (2009) [45] | RCT    | 51         | M 33 F 18 HS / BPTB Not stated     | Guided therapy: 3 (0.07) Knee class: 15 (0.33) | Low                   | Late (15–12) | Pre-operative 6 and 12 | IKDC knee evaluation form, Lysholm knee score, Tegner activity level scale, isometric ext (90deg), single hop for distance, ROM |
| Schenck et al. (1997) [46] | RCT    | 37         | M 28 F 9 BPTB Not stated           | Home 2.85 (0.12)Clinic 14.2 (0.06) | Low                   | Mid (0–6)      | Pre-operative, 3 and 12 | ROM, Lysholm knee score, VAS pain, single hop for distance, KT-1000, SP, level of activity, surgery satisfaction |
| Tracey et al. (1997) [47] | Retrospective | 39        | M 54 F 15 BPTB Competitive recreational athletes (80%) | Home 7.3 (0.03) Minimally compliant subgroup: 12 (0.05) Clinic: 60 (2.5) Non-compliant subgroup: 1.7 (0.07) | Mod                   | Mid (0–6)   | 16 (12–30) | ROM, anterior draw, Lachman’s, pivot shift, Lysholm knee score, activity level (4 levels), surgery satisfaction |
| Ugutmen et al. (2008) [48] | RCT    | 104        | M 103 F 1 HS Not stated            | Home unspecified Clinic: unspecified | Unspecified          | 0–8          | Mean 21.1 (12–66) | X-ray, MRI, subjective comments from patients, thigh atrophy, NPRS, effusion, ROM, KT-1000, PFJ pain and crepitation, Lachman’s, pivot shift, anterior drawer, Lysholm knee score, HSS, IKDC knee evaluation form |
| Yu et al. (2017) [49]    | Retrospective | 42        | M 39 F 3 BPTB Not stated           | Rupture: 18 (0.35) No rupture: 186 (0.36) | Mod                   | 0–12         | N/A              | Re-rupture |

ACLR anterior cruciate ligament, ADLs activities daily living, BPTB bone-patella-tendon-bone, deg degree, ext extension, F female, Fl flexion, FMS functional movement screen, HS hamstring, HSQ Health status questionnaire, HSS hospital of special surgery, IKDC International knee documentation committee, KOOS knee injury and osteoarthritis outcome score, KOS-ADL knee outcome survey–activities of daily living, K-SES knee-self-efficacy scale, m metre, M male, MCS mental component summary, MRI magnetic resonance image, NPRS numeric pain rating scale, OSL overall stability index, PCS physical component summary, PFJ patellofemoral joint, RCT randomised controlled trial, ROM range of motion, RTS return to sport, sec seconds, SF-36 short form-36, SIP sickness impact profile, VAS visual analog scale
To determine the correlation between frequency of supervised rehabilitation and rehabilitation outcome, the frequency of appointments in each intervention group was mapped based on the average number of weekly appointments across the intervention period. Patients who attended less than once per month were classified as low, between 1 and 2×/month as moderate and more than twice per month as high across the duration of their rehabilitation.

The intervention period was labelled according to the stages of rehabilitation the intervention spanned: early-stage (0–3 months), mid-stage (0–6 months) and late-stage (0–6 months+). Eight studies investigated through to the late phase [32, 35, 39, 40, 44, 45, 48, 49], nine mid-stage [30, 31, 33, 36, 41–43, 46, 47] and two early-stage [37, 38]. Only five studies had a follow-up assessment period longer than the intervention period [31, 34, 37, 41, 47].

Thirteen of the included 20 studies showed no significant difference between low, moderate or high frequency supervised rehabilitation regardless of the intervention period. The non-significant studies were all seven RCTs [31, 37, 38, 40, 45, 46, 48], five retrospective studies [34, 35, 41, 47, 49] and one prospective study [36]. Seven studies, all published in the last 4 years, showed an association between improved outcome and moderate or high-frequency supervised rehabilitation. Specifically, prospectively designed studies found associations between proprioception recovery [42], functional knee movement [42], higher return to preinjury level of sports [44] and better quality of life [44] in a highly supervised group than in a low supervision home-based group.

Studies utilising a retrospective methodology found an association between higher rehabilitation utilisation and significantly higher patient reported outcomes (Knee Outcomes Survey–Activities of Daily Living (KOS-ADL) scale [32, 43], Knee Injury and Osteoarthritis Outcome Score subscales [39], patient satisfaction [47] and numerical pain rating scale [43]), greater return to preoperative activities [39, 47] and improved Lysholm knee score [39, 47]. Finally, in a cross-sectional study, Dempsey et al. (2019) found a weak positive correlation with isokinetic knee extension torque and level of supervision [30], while Darain et al. (2015) demonstrated a successful return to sport at 6 months with a high frequency of supervised rehabilitation in a case report [33].

Summary

Despite significant heterogeneity between the included studies and overall poor quality of research, it is reasonable to conclude that a moderately or minimally supervised rehabilitation program is at least as effective as a fully supervised high-frequency rehabilitation program. Recent publications, however, are showing an association between higher rehabilitation utilisation improving outcomes. It remains to be seen whether there is an optimal frequency of supervised rehabilitation visits and if this varies between stages of rehabilitation. From the current research, it is unclear whether participants met an acceptable level of function for return to sport and minimisation of reinjury.

Supervised Rehabilitation Duration

Original Studies

Of the eight included original studies regarding supervision duration, seven studies are retrospective and one prospective in design (Table 4). The average age was 27.9 (26.2–29.7). Seven studies utilised a hamstring graft, while one study used both BPTB and hamstring graft. Participant activity level was reported in all but one study but was largely poorly defined. All studies compared a group of patients who completed a shorter duration of supervised rehabilitation (less than 3 or 6 months) to a group of patients who completed six or more months of rehabilitation, including structured agility, gym exercises, landing and on-field rehabilitation in line with current evidence-based recommendations.

Supervised rehabilitation longer than 6 months was associated with improved outcomes at all assessment time points. Specifically, associations were found between longer supervised rehabilitation and functional symmetry [50, 51], a greater likelihood of meeting return to sport criteria and RTS at 12 months [50, 51], double leg vertical hop landing symmetry [52, 53], knee flexor rate of torque development and symmetry [54], speed and agility [55], knee extensor muscles torque parameters and LSI values [56] and better subjective outcomes [57]. Delaying the start of rehabilitation longer than one month after reconstruction was negatively associated with objective outcomes [57]. However, the duration of supervised rehabilitation was not associated with one leg vertical hop symmetry [53], knee joint stability, thigh and knee joint circumferences, active range of motion or everyday pain [55].

Summary

It is reasonable to conclude that a longer duration of supervised rehabilitation of at least 6 months, which includes structured agility, gym exercises, landing and on-field rehabilitation, is associated with more favourable outcomes after ACL reconstruction. It is likely that 9 or 12 months of structured supervised rehabilitation would offer further benefits. High-quality prospective randomised trials in this area are required.

Adherence and outcome

Reviews

All three reviews evaluated adherence to clinic and home-based rehabilitation against functional and
| Author (year)            | Design            | Population | Investigation | OM assessment (months) | OMs                                                                 |
|-------------------------|-------------------|------------|---------------|------------------------|----------------------------------------------------------------------|
| Ebert et al. (2019) [50]| Retrospective     | 111        | M 73 HS M F3  | Level of post-operative rehabilitation completed (7 point scale)   | 12.5 (at RTS) NSARS, single hop for distance, triple hop for distance, 6m timed hop, triple crossover hop for distance, isokinetic Fl and ext (90deg/sec) |
| Edwards et al. (2017) [51]| Retrospective     | 113        | M 75 HS M F3 | Level of post-operative rehabilitation completed (7 point scale)   | 10-14 IKDC subjective knee evaluation, NSARS, single hop for distance, triple hop for distance, 6m timed hop, triple crossover hop for distance, isokinetic Fl and ext (90deg/sec), pass/fail of the test battery |
| Krolikowska et al. (2018) [52]| Retrospective  | 38         | M 38 HS M F3 | Sports participation Supervised rehabilitation < 6 months and > 6 months | Average of 2 years IKDC knee evaluation form, DL and SL vertical hop analysis, Lachman’s, pivot shift |
| Krolikowska et al. (2018) [53]| Prospective   | 35         | M 35 HS M F3 | Not stated Supervised rehabilitation < 6 months and > 6 months | 7 (end of stage 4) IKDC knee evaluation form, DL and SL vertical hop analysis |
| Krolikowska et al. (2019) [54]| Retrospective  | 143        | M 143 HS M F3 | Sports participation Supervised rehabilitation < 6 months and > 6 months | 7 (end of stage 4) Isokinetic Fl (180deg/sec) |
| Krolikowska et al. (2018) [55]| Retrospective  | 30         | M 30 HS M F3 | Sports participation Supervised rehabilitation < 3 months and > 6 months | 8 IKDC knee examination Form, VAS pain, agility test (speed and time) |
| Krolikowska et al. (2018) [56]| Retrospective  | 30         | M 30 HS M F3 | Sports participation Supervised rehabilitation < 3 months and > 6 months | 8 Isokinetic Fl and ext (180deg/sec and 60deg/sec) |
| Rosso et al. (2018) [57]| Retrospective     | 174        | M 141 HS/ BPTB F 35 | Sports participation Supervised rehabilitation < 3 months and > 3 months | 3.75 years IKDC knee evaluation form, pivot shift, Lachman’s, anterior craking, single hop for distance, Lysholm knee score, IKDC subjective knee evaluation, return to sport status, SPORTS score, ACL-RSI, re-rupture |

ACL anterior cruciate ligament, ACL-RSI anterior cruciate ligament—return to sport after injury, BPTB bone patella tendon bone, deg/sec degrees per second, DL double leg, ext extension, F female, Fl flexion, HS hamstring, IKDC International knee documentation committee, LSI limb symmetry index, m metre, M male, NSARS Noyes sports activity rating scale, SL single leg, SPORTS subjective patient outcome for return to sports.
subjective outcomes (Table 5). There is an overall lack of evidence in the area of adherence and its effect on rehabilitation. Two reviews demonstrated a positive relationship between greater adherence to rehabilitation and improved outcomes [58, 60], while one review was inconclusive [59]. The methodological quality of included studies is uncertain as it has yet to be evaluated appropriately.

Original studies
Of the four included original studies regarding adherence, three studies of prospective design compared measures of adherence to clinic and home-based rehabilitation against functional and subjective outcomes over the first 6 weeks, 8 weeks and 6 months of rehabilitation (Table 6). The average age was 28.4 (26.9–29.4). One study used both BPTB and hamstring graft; the other two studies did not state. Participant activity level was stated in two studies. Outcomes were assessed at six months and 9–12 months.

It is inconclusive whether adherence has a positive effect on outcome. Significant correlations have been demonstrated between greater adherence to clinic-based rehabilitation and improved Knee Outcomes Survey–Sports Activities Scale scores [63] and one leg hop [62]. On the contrary, no significant correlation was found between any OMs and adherence measures in one study [64] and Brewer et al. (2004) found greater adherence to clinic-based rehabilitation was associated with high Lachman’s grade [63]. Adherence to home-based rehabilitation negatively predicted Cincinnati Knee Rating System–Sport scores [64] and was a negative correlate to all OMs for participants > 30 years, but a positive correlation if < 30 years [64]. There was also no difference in any outcome measure with adherence to a web informational support system, despite the intervention group reporting being more committed to rehabilitation [61].

Summary
When considered with the results of the included reviews and the conflicting results of the few original studies investigating adherence to clinic and home-based rehabilitation against outcomes, an overall conclusion cannot be made on the effects of adherence to rehabilitation and outcome.

| Author (year) | Review type | Dates | Methodological quality | No. Included original studies | Conclusion |
|---------------|-------------|-------|------------------------|------------------------------|------------|
| Christina et al. (2015) [58] | Non-systematic | Not specified | Not assessed | N/A | Positive correlation |
| Mendonz et al. (2007) [59] | Systematic | Until 2006 | Not assessed | 3 | Inconclusive |
| te Weerik et al. (2013) [60] | Systematic | 2001–2011 | Good | 1 | Positive correlation |

Methodological quality refers to the outcome or presence of a quality appraisal undertaken by the review not the authors of this study. The conclusion stated is that of the included review in reference to the correlation between adherence and rehabilitation outcome. The number of original studies is only those included in each review in the evaluation of adherence and outcome.
| Author (year) | Design | Population | Investigation | Adherence measure | OM assessment (months) | OMs |
|---------------|--------|------------|---------------|-------------------|-----------------------|-----|
| Brewer et al. (2004) [63] | Prospective | 108 | M 72, F 30 | Adherence to clinic and home-based rehabilitation in the first 6 weeks | Adherence to appointments (% attended of scheduled) Adherence to home-exercise prescription (self-report diary and hidden tape play counter) Adherence during appointments (SIRAS) | Adherence during appointments (SIRAS) | 6 | Single leg hop for distance, Lachmans, KOOS-SAS |
| Brewer et al. (2000) [62] | Prospective | 95 | M 67, F 28 | Competitive (52%) Recreational (43%) Non-athletes (3%) | Adherence to clinic and home-based rehabilitation in the first 6 months | Adherence to appointments (% attended of scheduled) Adherence to home-exercise prescription (0–10 self-report adherence) Adherence during appointments (SIRAS) | Adherence during appointments (SIRAS) | 6 | Lysholm knee score, KT-1000, single hop for distance |
| Levinger et al. (2017) [61] | Pilot RCT | 17 | M 9, F 8 | Not stated | Adherence to a web informational support service | Adherence to recommended website usage (% out of 22) | 3 | KOOS, K-SES, FABQ, TSK-SF, IPAQ, qualitative interview |
| Pizzari et al. (2005) [64] | Prospective | 68 | M 48, F 26 | Competitive (63%) | Adherence to clinic and home-based rehabilitation in the first 8 weeks | Adherence to appointments (% attended of scheduled) Adherence during appointments (SIRAS) Adherence to home-exercise prescription (self-report diary, % exercises completed) | Adherence during appointments (SIRAS) | 9-12 | IKDC knee evaluation form, IKDC subjection knee evaluation, CKRS, KOOS, 6m timed hop, triple crossover hop for distance |

**OMs** = outcome measures, **RCT** = randomised controlled trial, **SIRAS** = sports injury rehabilitation adherence scale, **TSK-SF** = Tampa scale for kinesiophobia - short form
Self-motivation was associated with home exercise completion [62, 71, 74]; this was true for older participants only in one study [73]. A high athletic identity in younger patients was associated with home exercise completion [73]. However, in two studies, athletic identity was not correlated with adherence to clinic or home-based exercise [62, 75]; except on days with high-stress, participants with high athletic identity completed more exercises [75].

Social support was not found to be significantly related to home exercise completion [62], except in older participants [73]. High stress and mood disturbance were negatively associated with home exercise completion. Neuroticism was not related to adherence, and participants with low pessimism were able to complete more prescribed exercises on days where they had more pain [75]. Goal setting and positive self-talk were significant positive correlates to home exercise adherence [72]. These were not related to clinic attendance or cryotherapy completion [72]. Autonomy had a positive relationship with rehabilitation adherence [74], and the Big 5 personality traits of agreeableness and conscientiousness were significantly correlated with adherence measures [74].

Summary
There are a variety of psychological variables which may affect a person’s adherence to rehabilitation; however, we did not investigate whether interventions to address these factors would lead to an increase in adherence. Further research aimed at addressing these factors and the effect that they have on rehabilitation adherence and subsequent patient outcomes is warranted.

Patient Perceptions
Table 9 details the thematic synthesis of patient-perceived barriers to and facilitators of rehabilitation. Fifteen original studies were included in the analysis. Eight studies used a qualitative methodology [15, 20, 80–85], four mixed methods [30, 77–79], one pilot RCT [61], one case series [71] and one prospective cohort study [86]. Fifty-five raw themes were categorised into three overall themes (environmental, personal and...
| Author (year)         | Design          | Population | Concepts investigated | OMs                      | Adherence measures                                                      |
|----------------------|-----------------|------------|-----------------------|--------------------------|------------------------------------------------------------------------|
| Brewer et al. (2003) | Prospective     | 61         | M 40 F 21             | Self-motivation, Athletic Identity, Social support | SMI, SSI, AIMS, BSI, Rehabilitation attendance index (attended/scheduled), SIRAS, Self-reported home rehabilitation adherence (0–10 scale) |
| Brewer et al. (2013) | Prospective     | 91         | M 58 F 33             | Stress and mood, Athletic Identity, Neuroticism, Pessimism | AIMS, NEO-FFI, PESS, LOT-R, POMS-B, Lysholm knee score, NPRS, daily stress 0-5 scale, SIRAS, Self-reported home rehabilitation adherence (0–10 scale) |
| Brewer et al. (2000) | Prospective     | 95         | M 67 F 28             | Self-motivation, Athletic Identity, Social support | SMI, SSI, AIMS, BSI, KT1000, single leg hop for distance, Rehabilitation attendance index (attended/scheduled), SIRAS, Self-reported rehabilitation adherence diary (0–10 scale) |
| Chan et al. (2003)   | Retrospective   | 95         | M 94 F 21             | Autonomy, Self-motivation | HCCQ, TSRQ, Combined items from the SIRAS and Modified Patient Self-Report Scales of Their Home-based Rehabilitation Adherence |
| Hilliard et al. (2004) | Prospective   | 108        | M 72 F 36             | Personality traits       | NEO-FF, SIRAS, Rehabilitation attendance index (attended/scheduled) |
| Niven et al. (2012)  | Prospective     | 87         | M 65 F 28             | Theory of planned behaviour (self-efficacy, intention) | Attitudes towards ACL Rehabilitation Questionnaire, Self-reported rehabilitation adherence (0–7 scale) |
| Rock and Jones (2002) | Case series     | 3          | M 1 F 2               | Social support, Self-motivation, Counselling | SSBS, emotion scores in ERAIQ, NPRS, perceived rehabilitation completion (0-100 scale), SIRAS |
| Scherzer et al. (2001) | Prospective    | 54         | M 37 F 17             | Goal setting, Imagery, Positive self-talk, Perception | Sports Injury Survey subscales (goal setting, healing imagery, positive self-talk), Rehabilitation attendance index (attended/scheduled), Self-reported rehabilitation adherence (0–10 scale) |

AIMS: athlete identity measurement scale, BSI: brief symptom inventory, ERAIQ: emotional response of athletes to injury questionnaire, HCCQ: health care climate questionnaire, LOT-R: the life orientation test-revised, NEO-FF: neuroticism five-factor inventory, NPRS: numerical pain rating scale, PESS: pessimism, POMS-B: negative mood–profile of mood states-B, SIRAS: sports injury rehabilitation adherence scale, SMI: self-motivation inventory, SSBS: social support behaviours survey, SSI: social support inventory, TSRQ: treatment self-regulation questionnaire.
treatment-related) and nine sub-themes as detailed in Table 10.

Each theme was tallied on the number of times it was mentioned across the literature. A theme was only tallied once per article. The tally does not imply the weight of the barrier or facilitator on the subjects but only how often the factor has emerged in the research. Under the personal category, any theme relating to the mental and emotional state of a person, affecting, or arising in the mind was classified as psychological. However, any theme involving, or relating to, exhibiting a behaviour was categorised as behavioural. A factor could be both a facilitator and barrier. For example, interaction with family and friends may be a barrier if it involved sympathy, caution and worry from family and friends, but a facilitator if it involved support, motivation and encouragement.

Treatment-related factors were mentioned 82 times across three sub-themes (delivery of care, digital health and group rehabilitation) consisting of 32 raw themes; 36 mentions as a barrier to and 46 mentions as a facilitator of rehabilitation. Personal factors were mentioned 51 times across three sub-themes (psychological, physiological and behavioural), consisting of 19 raw themes; 28 mentions as a barrier and 23 mentions as a facilitator. Environmental factors were mentioned 19 times across two sub-themes (social and societal), consisting of four raw themes; 11 mentions as a barrier and eight mentions as a facilitator.

The most common raw themes arising in the literature as either a barrier or facilitator of rehabilitation were therapeutic relationship (n = 11), interaction with family and friends (n = 9), self-motivation (n = 9), fear of reinjury or return to sport (n = 7), organisation/lack of time (n = 6), interpersonal comparison (n = 6), interaction with team and coaches (n = 5), access to facilities and equipment (n = 4), expectations (n = 4), pain, weakness or illness (n = 4), length and commitment of rehabilitation (n = 4) and enjoyment (n = 4).

**Summary**

These results signify the key role the treating health practitioner plays in setting an appropriate rehabilitation environment to reduce treatment-related barriers to and enhance facilitators of rehabilitation but also support the athlete with a strong therapeutic relationship which fosters motivation and enjoyment. Specific personal factors related to the individual may be able to be addressed through therapeutic exercises (e.g. fear of reinjury) or may require tailored interventions or alternative professionals to facilitate rehabilitation. Social and societal factors also play a key role but are harder to influence by the practitioner.

**Other factors**

The three included original studies investigated associations between clinician experience and qualification [87], graft choice and meniscal injury [30] and participant sport [70] on rehabilitation adherence (Table 10).

To determine physiotherapist practice patterns, Greenberg et al. (2018) surveyed 1074 physiotherapists from the USA. They found clinicians with less clinical experience, higher volumes of patients post ACL reconstruction and an orthopaedic clinical specialist or sports clinical specialist certification deliver a longer overall duration of clinical care more in line with clinical recommendations [87].

In terms of graft choice and meniscus injury, Dempsey et al. (2019) found that competitive and recreational athletes who received a BPTB graft completed more days of rehabilitation per week and had more total visits compared with patients who received an HT graft; however, meniscal procedures did not correlate with rehabilitation quantity [30].

In a prospective study, Niven et al. (2012) found variation in the adherence levels across different sports, indicating that Gaelic football, hockey, rugby and soccer players consistently adhered well, whereas motocross participants were poor adherers [70]. The level of sport had a positive relationship, indicating that a lower level of participation was associated with higher adherence levels [70].

**Summary**

Newly graduated and specialty trained therapists may be more cognisant of current evidence and delivery care more in line with current recommendations. Although patients with BPTB graft attended more often, it is unclear what this may be due to and the implications for rehabilitation adherence. Finally, it is unclear as to the reasons why different sports have different levels of adherence.

**Discussion**

Participation in ACL rehabilitation is considered critical to facilitate return to sport [14, 51, 88]. In this scoping review, 71 articles relating to adherence and participation in ACL rehabilitation published between 1997 and 2019 were identified. A key finding of this review was that a longer duration of supervised evidence-based rehabilitation is correlated with more favourable outcomes post ACL reconstruction; however, the optimal frequency of rehabilitation supervision and the level of adherence required to a rehabilitation program is yet to be determined. It is reasonable to conclude that from current evidence, a minimally or moderately supervised rehabilitation program is at least as effective as a fully supervised high-frequency rehabilitation program.
| Factor                  | Barrier | Facilitator | Total |
|------------------------|---------|-------------|-------|
| Environment            | 11      | 8           | 19    |
| Social                 | 6       | 8           | 14    |
| Interaction with family and friends | 3       | 6           | 9     |
| Interaction with team and coaches | 3       | 2           | 5     |
| Societal               | 5       | 0           | 5     |
| Access to facilities and equipment | 4       |              | 4     |
| Access to skilled providers | 1       |              | 1     |
| Personal               | 28      | 23          | 51    |
| Psychological          | 16      | 15          | 31    |
| Fear                   | 7       |             | 7     |
| Self-motivation (low/high) | 4       | 5           | 9     |
| Met or unmet expectations | 2       | 2           | 4     |
| Restlessness and impatience | 1       |             | 1     |
| Hopelessness/Belief    | 1       | 1           | 2     |
| Previous experience (bad/good) | 1       | 1           | 2     |
| Progress changeability | 1       |             | 1     |
| Acceptance             | 1       |             | 1     |
| Positive attitude      | 2       |             | 2     |
| Feeling appreciated    | 1       |             | 1     |
| Luck                   | 1       |             | 1     |
| Physiological          | 6       | 2           | 8     |
| Pain, weakness and illness | 4       |             | 4     |
| Significant injury     | 1       |             | 1     |
| Second injury          | 1       |             | 1     |
| Maintain health and fitness | 2       |             | 2     |
| Behavioural            | 6       | 6           | 12    |
| Organisation/lack of time (poor/good) | 5       | 1           | 6     |
| Goal setting           | 1       | 2           | 3     |
| Persistence            | 2       |             | 2     |
| Distraction (new activities) | 1       |             | 1     |
| Treatment-related      | 36      | 46          | 82    |
| Delivery of care       | 18      | 13          | 31    |
| Length and commitment of rehabilitation | 4       |             | 4     |
| Non-sport specific exercise | 2       |             | 2     |
| Restrictions in activities | 2       |             | 2     |
| Enjoyment              | 2       | 2           | 4     |
| Patient control (low/high) | 2       | 1           | 3     |
| Insurance              | 2       | 1           | 3     |
| Assessment of progress | 1       | 3           | 4     |
| Speed of progression of exercises (slow/fast) | 1       | 1           | 2     |
| Early therapist discharge | 1       |             | 1     |
| Cost                   | 1       |             | 1     |
| Individualised program | 3       |             | 3     |
Furthermore, many factors were associated with a patient’s ability to adhere to and participate in rehabilitation. Psychological factors of self-motivation, athletic identity, stress and mood disturbance, goal setting, positive self-talk and the personality traits of optimism, agreeableness and conscientiousness were associated with rehabilitation adherence. Numerous patient-perceived barriers to and facilitators of rehabilitation were identified. The most common were the therapeutic relationship, interaction with family and friends, self-motivation, fear of reinjury and organisation/lack of time.

Table 9 Frequency of mention count for each theme identified in the synthesis of included original studies investigating ‘patient perceptions’ (Continued)

| Factor                              | Barrier | Facilitator | Total |
|-------------------------------------|---------|-------------|-------|
| Comfort and convenience             | 1       | 1           |       |
| Cryotherapy                         | 1       | 1           |       |
| Provider factors                    | 12      | 13          | 25    |
| Therapeutic relationship            | 4       | 7           | 11    |
| Physiotherapist as a guide and coordinator | 2       | 2           | 4     |
| Coordination between providers      | 3       | 2           | 5     |
| Information availability            | 3       | 2           | 5     |
| Digital health                      | 3       | 8           | 11    |
| Poor accessibility                  | 1       | 1           |       |
| Uncertainty of technique and safety | 1       | 1           |       |
| Familiarity with digital devices    | 1       | 1           | 2     |
| Blended care model                  | 2       | 2           |       |
| Informational and instructive      | 2       | 2           |       |
| Reminder for exercise completion    | 2       | 2           |       |
| Viewed as the future                | 1       | 1           |       |
| Group rehabilitation               | 3       | 12          | 15    |
| Interpersonal comparison           | 2       | 4           | 6     |
| Social interaction                  | 2       | 2           | 2     |
| Informational support               | 2       | 2           |       |
| Fun and enjoyable                   | 2       | 2           |       |
| Motivation and support              | 2       | 2           |       |
| Innovative                          | 2       | 2           |       |
| Obligation                          | 2       | 2           |       |
| Adequate monitoring and adaptability| 2       | 2           |       |

Bold text highlights each key theme and sub-theme.

Table 10 Summary of included original studies investigating ‘other factors’

| Author (year)       | Design       | Population | Age (mean) | Sex | Activity level | Concepts investigated | OMs | Comparators                  |
|---------------------|--------------|------------|------------|-----|----------------|-----------------------|-----|-----------------------------|
| Dempsey et al. (2019) [30] | Mixed methods | 60         | 29.7       | M 31 | Competitive (57%) Recreational (41%) Non-athletes (2%) | Graft type Meniscus injury | Sessions attended | BPTB or HS graft Meniscus injury |
| Greenberg et al. (2018) [87] | Cross-sectional | 1074       | N/A        | N/A | N/A | Physiotherapist practice patterns | N/A | N/A                         |
| Niven et al. (2012) [70]   | Prospective  | 87         | 29         | M 65 | Not stated | Level and type of sport | Attitudes towards ACL Rehabilitation Questionnaire | Self-reported rehabilitation adherence (0–7 scale) |

M male, BPTB bone patella tendon bone, F female, HS hamstring, OCS orthopaedic certified specialist, SCS sport certified specialist
For the researcher and clinician, the results of our scoping review highlight the need to develop appropriate rehabilitation protocols that not only develop the physical capabilities of patients but also take into account patients’ circumstances and psychology, which may pose barriers to achieving a successful outcome. Aspects of rehabilitation may need to be varied depending on the individual presenting.

**How Much Supervision Is Required, and For How Long?**

It would be premature to conclude that reducing rehabilitation supervision during ACL reconstruction is required. Current practice patterns in Australia reflect a decreasing frequency of supervised rehabilitation from once or twice per week in the early phases, to less frequent visitation with a focus on independent exercise with periodic review as rehabilitation progresses [89]. The evidence in this review is inconclusive as to whether this is the most appropriate way to manage patients.

Based on our results, the duration of supervised rehabilitation may be more important than frequency. Supervised rehabilitation should begin shortly after surgery [57], continue for greater than 6 months (ideally 9–12 months) and include a tailored gym program, landing, agility, on-field rehabilitation and a structured return to sport. It appears that two patients performing the same rehabilitation program can achieve the same outcome regardless of supervision or adherence level; however, it remains to be seen whether patients have the knowledge and skills to complete rehabilitation at the appropriate intensity to achieve return to sport criteria without appropriate supervision [55].

Recent original studies have demonstrated that even with well-controlled and implemented rehabilitation, most athletes fail to meet discharge criteria [90]. Furthermore, in the community, only 30% of patients complete any form of rehabilitation beyond 6 months [91] and only 5% of people complete evidence-based rehabilitation. Edwards et al. (2017) demonstrated only 21% of patients who had completed rehabilitation and 5% of patients who had completed rehabilitation passed a RTS test battery before RTS [46]. Therefore, even if patients do complete rehabilitation, the end phase of rehabilitation is typically not extensive or specific enough, failing to expose patients to specific training loads and training characteristics necessary before they return to unrestricted sport [90]. Due to the knowledge and skills required to execute late-stage rehabilitation to a sufficient standard and intensity, a higher level of supervision may be needed in the later phases to meet return to sport criteria and reduce the risk of reinjury [50, 51, 55].

All original studies which showed a positive relationship between supervised rehabilitation frequency and outcomes were published in the last 4 years. This fact may suggest that modern rehabilitation programs may require more guidance from a clinician. Age may also play a role in the frequency of supervision required. Younger patients, particularly under 18, may require a higher frequency to achieve successful outcomes by providing extra guidance on exercises, goals and motivation to adhere to post-operative rehabilitation [43, 46, 64].

Clinician knowledge may also play a role in achieving a successful outcome. Clinicians familiar with current best practice who service a higher volume of patients who have undergone ACL reconstruction are more likely to provide evidence-based care, while less familiar clinicians may be at risk of prematurely discharging patients before meeting established RTS criteria [87]. This may be due to a lack of confidence, skills or resources in the performance of late stage rehabilitation and return to sport criteria. Clinicians, therefore, need to be aware of their own limitations and potentially refer to other health professionals.

A final point to consider is that the increasing demand for cost-effective health care interventions is leading to the development of more unsupervised rehabilitation protocols [25]. Rehabilitation needs to be both effective and economical. There are substantial financial advantages of more patient-directed rehabilitation in reducing costs for the appointment, travel time, inconvenience, time off work and comfort [25, 34, 35]. This presents a tough challenge for clinicians to ensure that patients have access to appropriate rehabilitation to achieve functional and sporting goals, but not increase the undue financial burden upon the patient, health care system and industry [37]. No articles in this review included a cost-benefit analysis, which would aid in the development of a more robust research base and allow us to gain further insight into how to minimise costs and maximise outcome.

When designing future research to examine the adherence and outcome relationship, it is critical that researchers consider the definition of adherence, parameter, adherence measure and the value for acceptable adherence [91]. The studies detailed in this review [61–64] used a variety of measures including self-report diary, sessions attended, adherence within session (SIRAS) and hidden tape player counters. Multiple systematic reviews have highlighted a lack of a single valid and reliable measurement tool of adherence means that the relative effectiveness of interventions is difficult to compare across studies [92–94]. In a recent systematic review by Bailey et al. (2018) [91], the authors concluded there is a lack of sufficient consistency in adherence parameters, measures and values to inform a definition of adherence to therapeutic exercise or the required content of a suitable measure. The definition by Frost et al. (2017)
Can We Improve Rehabilitation Adherence and Participation?

Despite our improved understanding of what components need to be included within an evidence-based ACL rehabilitation [14], little consideration is given to why patients cease rehabilitation and the barriers which patients face in their rehabilitation journey [30].

Psychological factors, particularly fear of reinjury, are the most significant contributor to not returning to sport [96]. The results of this review support the notion that psychological variables contribute to patients ceasing or failing to adhere to rehabilitation. Self-efficacy was consistently reported as a significant mediator of successful surgery and rehabilitation [61]. Strategies to enhance patients’ self-efficacy have the potential to improve related barriers to participation, such as self-confidence, locus of control, autonomy support and stress and mood disturbance [97]. Likewise, the enhancement of patient self-motivation improves the chance they will persist with rehabilitation [98]. Patients can draw extrinsic motivation from the physiotherapist and rehabilitation program (e.g. progressing exercises, reassessing progress, goal setting, social and informational support) and therefore, increase their likelihood to participate in and progress through an appropriate duration of rehabilitation [58, 59]. Put together with the appropriate progression of exercises to expose patients to psychologically challenging but safe situations, fear of reinjury could also be reduced, increasing the likelihood of a return to sport and reducing reinjury [60]. Clinicians also need to be aware that some patients may require referral to an appropriate health care professional to receive specialised psychological care.

Especially due to the long rehabilitation process, by structuring or delivering rehabilitation in a manner that supports a positive psychological state (managing mood disturbance, enhancing and maintaining athletic identity and utilisation of goal setting and self-talk), many barriers to rehabilitation and return to sport can be overcome [60, 81, 85]. Further research into the utility of psychological intervention in ACL rehabilitation is needed [99].

How Can the Clinician Help the Patient?

Our results show a large number of patient-perceived barriers to and facilitators of rehabilitation. Many of the factors likely interact with each other, and by putting in place practices that either enhance facilitators or remove barriers, outcomes could be improved (Fig. 3).

As exemplified in our results, the physiotherapist plays a significant role in driving recovery by offering motivation, support, guidance, and encouragement while also providing informational support. It is also the physiotherapist’s responsibility to set realistic expectations and deliver a fun, progressive, sport-specific program for the individual with regular goal setting and reassessment. The physiotherapist can also assist in overcoming the physiological barriers to rehabilitation, such as pain and reduced health and fitness due to injury.

Group-based rehabilitation has the potential to overcome many of the barriers to and enhance facilitators of rehabilitation. Studies investigating group-based therapy demonstrated positive characteristics, including an enjoyable, cost-effective, social, supportive and motivating environment [80, 85]. Particularly with advancements in technology, the support of digital health technology is becoming increasingly valuable. By supporting face to face interactions, it provides a useful adjunct to improve exercise adherence, increase engagement, enhance the therapeutic relationship and provide informational support to

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![Thematic model depicting individual considerations required when planning ACL rehabilitation](image-url)
what is required at each stage, assisting in setting realistic expectations [81].

Environmental factors are harder to control as they are often out of the control of the treating physiotherapist. Physiotherapists working within team environments can assist by providing coaches and teammates with the appropriate information to facilitate inclusion and interaction with the main training group. If the physiotherapist has interaction with family members and friends, positive supportive behaviours can also be reinforced. Geographic constraints that prevent access to appropriate facilities and providers pose a particular challenge. Digital health may be an area of future research to address this domain.

Strengths and Limitations
This review is the first to address the effects of rehabilitation adherence and participation on ACL rehabilitation outcome. We were then able to provide the reader with potential influencing factors which create barriers to or facilitate rehabilitation. The review was also conducted according to recognised standards for scoping review following the development and publication of an a priori protocol.

The methodological quality of the articles was not assessed as per guidelines for conducting scoping reviews [16, 17]. Many studies were deemed as methodologically poor in quality, suggesting that more work is needed in developing good quality research in this area. There was no date limit on the search or inclusion. Included articles may not reflect contemporary practice due to changes in practice patterns through time.

When assessing the evidence for the frequency of supervised rehabilitation, it was not determined whether any cohort of patients achieved a successful outcome from their rehabilitation. Lynch et al. (2013) detailed the criteria for defining a successful outcome after ACL reconstruction. These are the absence of giving way, patient return to sport status, the absence of knee joint effusion, quadriceps muscle strength symmetry and meeting patient-reported outcome benchmarks [100]. Due to the outcome measure heterogeneity, it was not possible to evaluate whether a successful rehabilitation outcome was achieved. The level of compliance of patients in the included original studies within the frequency analysis to the home-based rehabilitation prescribed was also unknown [23].

Only articles published in English were available for inclusion, introducing a publication bias. Only one author screened, selected and extracted the data from the studies, potentially missing articles or introducing bias to data presented. The articles were categorised and analysed based on the author determined constructs. The categorisation may have been different for different authors.

Considerable heterogeneity between studies in outcome measures used, rehabilitation timeframes and programs reduced the ability to compare results directly. Most studies reported on participants over the age of 25, reducing the ability to draw conclusions for patients in a younger age group who typically have higher return to sport goals. Poor reporting of activity level and sport of the included participants leads to uncertainty in identifying factors relevant to specific athletes, sports or activity levels. Studies were from a variety of countries, introducing biases into the results due to different standards of care and access to health services. However, the review provides a comprehensive analysis of the current state of knowledge and areas where further work is needed to facilitate better rehabilitation practices.

Conclusion
This scoping review highlighted a broad spectrum of factors the clinician should consider when facilitating a patient’s rehabilitation after ACL reconstruction. Growing evidence suggests a longer duration of supervised rehabilitation involving agility, landing and gym exercises, and a supervised return to activity or sport is required to achieve functional and return to sport goals. The lack of conclusive evidence to support a specific supervised rehabilitation frequency fails to provide appropriate guidance to treating physiotherapists to deliver more optimal care.

Identification of the barriers to and facilitators of adherence and participation in ACL rehabilitation provides an opportunity for further research to be conducted to address personal, environmental, and treatment-related factors. Taking these factors into account increases the likelihood of patients complying with current best evidence rehabilitation to improve outcomes such as return to sport rates and reinjury.

Supplementary information
Supplementary information accompanies this paper at https://doi.org/10.1186/s40798-020-00258-7.

Additional file 1. Search

Abbreviations
ACL: Anterior cruciate ligament; RTS: Return to sport; PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analysis Extension for Scoping Reviews; RCT: Randomised controlled trial; BPTB: Bone patella tendon bone; OM: Outcome measure; KOS-ADL: Knee Outcome Score–Activities of Daily Living; SIRAS: Sport Injury Rehabilitation Adherence Scale

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AW made contributions to the design of the work, interpretation of data, drafting, writing for critical revision for intellectual content. WH and AL made contributions to the design of the study, interpretation of data and revision of the work. All authors gave final approval for the final version and agreed to be accountable for all aspects of the work.
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Availability of Data and Materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate
Not applicable.

Consent for Publication
Not applicable.

Competing Interests
Adam Walker is a practicing physiotherapist associated with a commercial entity which provides rehabilitation services to patients who have had an ACL reconstruction. Wayne Hing and Anna Lorimer declare that they have no conflicts of interest relevant to the content of this review.

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