Characteristics of return to running programs following an anterior cruciate ligament reconstruction: A scoping review of 64 studies with clinical perspectives

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ABSTRACT

Objective: To (1) describe return to running (RTR) programs used during rehabilitation after anterior cruciate ligament reconstruction (ACLR); and (2) provide clinical guidelines for RTR program after ACLR.

Design: Scoping review.

Literature search: We searched the MEDLINE (Pubmed), EMBASE, Web of Science and PEDro databases.

Study selection criteria: We included randomized controlled trial (RCT), cases series, meta-analyses, both scoping and systematic reviews including a rehabilitation program after ACLR with a specific RTR program. A "Running program checklist" (RPC) was elaborated based on the Template for Intervention Description and Replication (TIDieR), and on the Consensus on Exercise Reporting Template (CERT) checklist.

Data synthesis: The percentage and number of studies specifying each of the running program checklist items in their RTR program were reported. Number of items reported in each study and specific analysis item-by-item were also proposed.

Results: The "When (2)" item was the most frequently found (92.19%) and, conversely, the "Who (1)" item appeared only in four studies (6.2%). One-third of the studies presented only one item of the RPC, and 48 of the 64 articles discussed less than three items. Two studies described in detail their RTR program by reporting 8 and 9 items out of the 10, respectively. No study presented 10 of the PRC items.

Conclusion: There is a serious lack of information concerning RTR program following ACLR in the literature and further studies are needed to establish a program based on the best evidence.

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1. Introduction

Anterior cruciate ligament (ACL) is the most frequently injured knee ligament with an annual incidence of 85/100,000 exposures (Martin-Alguacil et al., 2018)(Wilk et al., 2012), and ACL tear can be associated with several other injuries such as collateral ligaments or meniscus (Ardern et al., 2014)(Hohmann et al., 2011). A large number of ACL injuries are treated with reconstructive surgery to achieve a stable knee and restore the mechanical properties of the knee with the goal of returning to the preinjury level of activity (Adams et al., 2012)(Hadizadeh, Amri, Roohi, & Mohafez, 2016a)(Hohmann et al., 2011). However, 3 years after the ACL reconstruction (ACLR), only 80% of patients return to sport (RTS), while 65% return to their preinjury sport and 55% return to competitive level (Ardern et al., 2014)(Ardern et al., 2016).

Rambaud et al. (Rambaud et al., 2018) highlighted that returning to running-activities (RTR) is an essential milestone in the return to
sport continuum with the transition from impairment-focused tasks to functional and sport-related tasks. These authors aimed to determine the criteria used in clinical decision-making for RTR after ACLR and suggested an individualized approach for each patient by combining both goal-based and time-based criteria (Rambaud et al., 2017). Although criteria for RTR are essential to answer to the question “when returning to running?”, it is also crucial to determine “how returning to running?”. To date, there is no consensus regarding which RTR program is recommended after an ACLR. RTR program is a broad term, and the running activity is often poorly defined (Rambaud et al., 2018). Various specificities such as intensity, frequency, duration of running session and progression criteria have not yet been clearly established.

At this stage, a state of the art synthesis aimed to characterize RTR programs used in literature during the rehabilitation after ACLR is required and, a scoping review is especially suitable for this type of exploratory research question (Colquhoun et al., 2014). In this context, we conducted a scoping review that aimed to: (1) describe the RTR programs used during rehabilitation of an ACLR; and (2) provide clinical guidelines for RTR program after ACLR.

2. Methods

This scoping review was conducted following the methodological framework proposed by Arksey and O'Malley (Arksey & O'Malley, 2005) and the Joanna Briggs Institute (Munn et al., 2014). Our research question was: ‘Which characteristics of running programs following primary ACL reconstruction are reported in the publications from the last ten years?’. We choose to limit the research to the past ten years considering that running field has been widely explored in the literature in the last decade and the continual advancements of the surgery procedures and rehabilitation protocols.

2.1. Selection criteria

The following criteria were employed to determine which articles were selected for the study (Table 1):

2.1.1. Type of studies

This scoping review included randomized controlled trial (RCT), cases series, meta-analyses, both scoping and systematic reviews including a rehabilitation program after ACLR with a specific RTR program. Concerning scoping and systematic reviews, only program and time to run or/and running/jogging elaborated by the authors themselves were considered. Magazine articles, conference abstracts, books, manuals, and personal opinions or techniques were excluded. Only publications in English were included to avoid translation bias, and the scope was limited to studies on human subjects performed within the last ten years.

2.1.2. Participants

Only studies including patients after primary ACL reconstruction were considered. Studies including patients after revision surgery or knee dislocations were excluded as these factors are known to slower the recovery. However, because Adams et al. (Adams et al., 2012) and Rambaud et al. (Rambaud et al., 2021) specified that ACL reconstruction associated with a meniscal repair involved no additional limitations on running progression, patients suffering from an associated meniscal lesion were included in the study. As there is no difference in terms of recovery between male and female, we selected studies including both sexes. Studies including patients under 18 years old were excluded as this population has an increased risk of graft failure and, therefore, requiring a specific running program (Kaeding et al., 2011). Studies including patients older than fifty-five years old were also excluded as they are more likely to have knee osteoarthritis that may influence recovery after surgery and therefore affect the RTR (Horváth et al., 2011).

2.1.3. Interventions

The influence on outcomes of graft choice or surgical technique remains a topic of controversy. Kaeding et al. (Kaeding et al., 2011) determined that there are increased risks of ACL graft re-rupture in patients who have undergone allograft reconstruction. The odds of graft re-rupture with an allograft reconstruction are 4 times higher than those of autograft reconstructions (Kaeding et al., 2011). Therefore, only studies of patients undergoing autograft ACLR were included in this study. The bone–patellar tendon is considered to be the gold-standard graft for an ACLR due to its biomechanical properties, but the donor site morbidity is higher than that of hamstrings (Martin-Alguacil et al., 2018). In this scoping, no preference in the choice of autograft type was made. Patients undergoing ACL reconstruction associated with major concomitant

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procedures (e.g. articular cartilage surgery, posterior cruciate ligament reconstruction, medial collateral ligament or lateral collateral ligament surgery) were excluded.

2.2. Study selection

The study selection was made in several steps. First, studies were identified using the MEDLINE (Pubmed), EMBASE, Web of Science and PEDro. The search was performed the 12 December 2020 and was limited to “English language” and “Publications in the last 10 years” (2010–2020). The search strategies are listed in appendix I. Second, for each result, the title and abstract were screened individually by two reviewers (xxx, xx). A third reviewer (AR) was available when a consensus on inclusion could not be reached. The inclusion criteria defined in Table 1 allowed the identification of the most relevant articles. Finally, the search was complemented by hand searching of the references of all articles selected for this review.

2.3. Data extraction and analysis

Two reviewers (xxx and xx) independently extracted data needed to make the scoping review: author and year of publication (1) study population (2), return-to-run criteria (3), details of running program (4).

Then, a personalized checklist called “Running program checklist” (RPC) (Table 2) was elaborated to determine what can be considered as a “running program”. This checklist was based on the Template for Intervention Description and Replication (TIDieR) (Hoffmann et al., 2014), and on the Consensus on Exercise Reporting Template (CERT) checklist (Slade et al., 2016). Page et al., (Page et al., 2017) reported that the TIDieR checklist helps authors in answering the questions “What, Who, How, Where, When and How much” with regards to intervention, however, TIDieR is not specific to exercise interventions. While the CERT is specific to exercise interventions, the RPC seemed to be more specific to running-activities. The RPC sets out 10 items that can be used to highlight information of a running program proposed in a study. To highlight the results of the scoping review, the data was represented in percentages. The checklist items were not considered as a scoreboard but rather as a summary of the existing scientific literature. In other words, the purpose of this scoping review was not to evaluate the methodological quality of different running programs but rather to focus on the existing scientific literature about running programs after an ACLR. Thus, an overview was provided of a more general issue than meta-analysis or systematic reviews that attempt to provide answers focused on more specific questions. In the same vein, the critical analysis of the quality of the studies included was not required in the present scoping review instead of a systematic review or a meta-analysis (Peterson et al., 2017).

3. Results

3.1. Flow of studies selection

The flow chart of studies selection is synthesized in Fig. 1. Inserting the research equation in the databases brought about 6219 results. Through identification, 5813 studies are obtained and after a selection of articles based on the relevance of their titles and abstracts and their inclusion of selected criteria, 57 studies were selected. Seven (n = 7) additional articles, which had not been identified during the primary search, were added to the reviews at this stage as they fulfilled all selection criteria.

The 64 studies included in this scoping review are collected in Fig. 2, which shows, per years, the number of articles, from January 2010 to December 2020, specifying a running program. The years submitting the most articles were 2013 and 2015. Of the 64 articles included in this scoping, 62.5% were published before 2016.

3.2. Synthesis of return to running programs

3.2.1. Overall analysis

Table 3 describes the percentage and number of studies specifying each of the running program checklist items in their running program. The “When (2)” item (when did the running program start) was the most frequently found, with 59 of the 64 articles (92.19%). Conversely, the “Who (1)” item (who gave the running program?) only appeared in four studies (6.2%), and is the checklist component the least reported in the included studies.

Table 4 presents how many items were reported in each study. One-third of the studies (n = 23; 35.9%) presented only one RPC item of Checklist, and 48 of the 64 articles discussed three or fewer items. Studies including two RPC items were far behind with a rate of 25%. Also, a total of 15.6% of the included studies provided information on 5 or more of the RPC items. Adams et al., (Adams et al., 2012) as well as Dauty et al., (Dauty et al., 2010) described in detail their RTR program by reporting 9 and 8 items out of the 10, respectively. No study presented 10 of the PRC items.

3.2.2. Specific analysis (Appendix 2)

3.2.2.1. Who? (1). Question (1) was: “Does the article specify whether the physiotherapist does supervise the realization of the running program or is the patient expected to do it himself?”. The four studies (Dauty et al., 2010) Havens et al., 2018) Sigward et al., 2016) (Wilk & Arrigo, 2017) reporting the “Who (1)” item,
monitored the training program with a logbook fulfilled by the patient. The authors stipulated that the patients themselves completed a home-based running program and only Wilk et al. (Wilk & Arrigo, 2017) reported a physician supervision of the running program.

3.2.2.2. When? Question (2) was: “Does the article stipulate when to start the running program?” and Question (3) was: “Does the article mention criteria for starting the running program?”.

The vast majority of studies based the decision to RTR on post-surgical delay (“When (2)”), most frequently 12 weeks (34/64 studies (53.1%)) and 16 weeks (5/64 studies (7.8%)) after surgery. Peebles et al. (Peebles et al., 2019) appraised the longest delay with a RTR at 20 weeks after ACL-R. Five articles (n = 5) (Buckthorpe et al., 2019) (Hoppeler, 2016) (Ito et al., 2021) (Nyland & Taniyama, 2019) (Yabroudi & Irrgang, 2013) did not specify the “When (2)” item. The “When (3)” item appeared in 20 studies (31.2%). Five of them (n = 5) specified full ROM (Cavanaugh & Powers, 2017) (Dauty et al., 2010) (Manske et al., 2012) (Panariello et al., 2016) (Yabroudi & Irrgang, 2013) and muscle strength criteria was mentioned in 7
articles (Adams et al., 2012)(Hartigan et al., 2010)(Ito et al., 2021)(Karasek et al., 2010)(Lemiez et al., 2011)(Manske et al., 2012)(Yabroudi & Irrgang, 2013). Adams et al.(Adams et al., 2012) proposed an approach combining assessment goal-based criteria (“When (3)”) - with time-based criteria (minimum 6 weeks after surgery) (“When (2)”). Indeed, the patient could RTR after 6 weeks when the quadriceps index was greater than 80% compared with the uninvolved leg, if there was no trace of knee joint effusion and if the patient understood the soreness rules, which allow the patients to manage their progression according to symptoms. Only Ito et al.(Ito et al., 2021) and Yabroudi & Irrgang(Yabroudi & Irrgang, 2013) proposed a unique performance-based criteria for RTR with no time based-criterion.

3.2.2.3. How? (4) (5) (6). Question (3) was: “Does the program specify the data used to evaluate the running session which will also evaluate the patient’s progression?”. Question (4) was: “Does it mention the type of training session?” and Question (5) was: “Does it specify how and when to progress?”.

3.2.2.4. How much (7) (8). Question (7) was “Does the program stipulate the number of runs to be performed per week?”, and Question (8) was: “Does the program specify how many days of rest and when?”. Eight studies (Adams et al., 2012)(Arundale et al., 2018)(Arundale et al., 2017)(Dauty et al., 2010)(Buckthorpe et al., 2019)(Dauty et al., 2010)(Nyland & Tanyiama, 2019)(Peebles et al., 2019)(Yabroudi & Irgang, 2013) mentioned “How much (7)” item (n = 8; 12.4%) and only 4 studies (Adams et al., 2012)(Dauty et al., 2010)(Manske et al., 2012)(Yabroudi & Irgang, 2013) specify the “How much (8)” item (6.2%). Yabroudi & Irgang(2013) as well as Manske et al.(Manske et al., 2012) set a running frequency every other day with a full rest day between jogging sessions. In comparison, Adams et al. (Adams et al., 2012) established no more than 4 times in a week in addition to a rest day between two runs. Dauty et al.(Dauty et al., 2010) mentioned 3 running sessions in a week, suggesting that other days were dedicated to rest or rehabilitation.

3.2.2.5. Where ? (9). Question (9) was: “Is the location mentioned: inside or outside?”. Twelve studies mentioned the location of the running sessions (Adams et al., 2012)(Ahlen & Liden, 2011)(Yvan Grinsven et al., 2010)(Hadizadeh, Amri, Roohi, & Mohafez, 2016b)(Larsen et al., 2015)(Lemiesz et al., 2011)(Milsom et al., 2014)(Larsen et al., 2015)(Shaw et al., 2019)(Waters, 2012)(Wilk et al., 2012)(Wilk et al., 2003)(Yabroudi & Irgang, 2013) (n = 12; 18.75%). Milsom et al.(Milsom et al., 2014) specified that the running sessions were performed outside, while Waters et al.(Waters, 2012) suggested on-court running sessions. The others proposed both indoor or outdoor running sessions. Wilk et al.(Wilk et al., 2012) and Adams et al.(Adams et al., 2012) specified the type of ground for the outside runs. Indeed, Wilk et al.(Wilk et al., 2012) suggested flat ground and Adams et al.(Adams et al., 2012) on track. Yabroudi & Irgang(Yabroudi & Irgang, 2013) as well as Wilk and al.(Wilk et al., 2012) proposed pool running. Wilk et al.(Wilk et al., 2012) suggested a backward pool running 4 weeks after surgery and forward pool running on week 6 prior to flat ground running as a way to initiate a jogging program.


4. Discussion

This scoping review’s first purpose was to highlight the characteristics of return to running programs proposed to patients after an ACLR during the last decade (2010–2020). The primary information from the present work was that the vast majority of studies appear not to consider the RTR phase with the same emphasis than other aspects of the ACLR rehabilitation. Indeed, most studies included in the present scoping review described in details the postoperative aims (e.g., quadriceps strengthening, range of motion restoration, neuromuscular training, … ) but provide very little information about the RTR program. While running is a fundamental movement skill required for many field and court sports, and rehabilitation guidelines after ACLR (Davies et al., 2017)(Sepúlveda et al., 2017)(Yvan Melick et al., 2016) emphasized that the postoperative rehabilitation lasted for 9–12 months, the RTR phase should be consider as an integral part of the ACLR rehabilitation.

4.1. The need to clearly identify the RTR phase within the ACLR rehabilitation and the return to sport continuum

The final goal after ACLR rehabilitation is to return to the pre-injury level of sport without risking new injuries or degenerative changes in the knee (Ardern et al., 2011). Return to sport (RTS) is not a decision taken in isolation at the end of the rehabilitation process but should be viewed as a continuum, paralleled with recovery and rehabilitation (Ardern et al., 2016). The RTS-continuum consists of a progression from “return to participation” (RTS-1) to “return to sport” (RTS-2) to “return to performance” (RTS-3) (Ardern et al., 2016). Based on the definition of the different phases of the RTS-continuum, RTR take place in the return to participation phase (modified training). Interestingly, while Ardern et al.(Ardern et al., 2016) recommend a criteria-based progression throughout the RTS-continuum, the vast majority of the included studies considered, for the RTR, a time-based criterion only. Ten studies used assessment-based criteria, relying on expert opinion. A recent study of Pairo de Fontenay et al.(de Fontenay et al., 2021) evaluated the validity of common assessment criteria and determined that an IKDC score >64 was the best predictor for a successful RTR after ACL-R.

With regards to the end of the RTR phase, no studies specified when it can be considered completed. According to Taberner et al.(Taberner et al., 2019), the RTS-continuum moves from high control to high chaos. In this “control-chaos” continuum, the RTR is viewed as a highly controlled activity. The authors suggested linear running until 80–85% of the maximum heart rate during 30 min without symptoms exacerbation or functional issues for progressing from high control to moderate control phase. We could use this criterion to consider the RTR completed. We think that all patients after ACL-R should reached this criterion as a strong basis of fundamental recovery. Specific programs including changes of direction, sprinting, or slope running, would be continued according to the patient goals.

4.2. The need to include all parameters that influence injury-risk and response to training regarding the RTS program

Considering, on the one hand, the high running-related injury incidence rate in the general population (Nielsen et al., 2014), and more specifically the high prevalence of knee symptoms exacerbation and anterior knee pain after ACLR (de Fontenay et al., 2021), and on the other hand, the low percentage of patients returning to sport at the same pre-injury level after ACLR (Ardern et al., 2011), it is reasonable to expect that the RTR is a critical step on the RTS-continuum, which is not completed by every patients. Inadequate management of training parameters such as distance, duration, frequency, intensity, as well as progression in running program parameters could explain some of these failures. However, the vast majority of the included studies did not provide information about...
4.3. The need to include specific interventions that limit knee joint loading during the RTR

Pairoit-de-Fontenay et al. (Pairoit-de-Fontenay et al., 2019) reported running biomechanics alterations from 3 months up to at least 5 years after ACLR, mostly the sagittal plane knee mechanics. Altered gait biomechanics following an ACL injury, and more specifically altered knee joint forces during running may generate a harmful effect on cartilage, which can accelerate the initiation and progression of knee osteoarthritis (Bowersock et al., 2017). Surprisingly, none of the articles included in this scoping review aimed to restore proper running biomechanics using running gait retraining which may be defined as a clinical intervention that aims to improve running biomechanics and clinical outcomes (Warne et al., 2017). The use of mirror retraining or real-time feedback are potential meaningful interventions to improve running biomechanics but scientific evidence is lacking in the context of ACL-R. Exacerbation of knee symptoms is the most common complain during RTR after ACL-R (de Fontenay et al., 2021). According to the tissue homeostasis model proposed by Dye (Dye, 2005), knee symptoms exacerbation results from an overloading of a knee joint with very low load tolerance after ACL-R. To minimize knee loading and knee symptoms during running, 3 studies (4.8%) suggested to unload the knee using a swimming pool before starting a running program on ground (Tian et al., 2016)(Wilk et al., 2012)(Yabroudi & Irgang, 2013). Similarly, Wilk et al.(Wilk et al., 2012) proposed an alternative to the swimming pool with an unloaded treadmill. This device is an intermediary for progressively preparing the knee’s sensitized structures to running loads (Hansen et al., 2017). For example, Coslick et al.(Coslick et al., 2019) proposed successfully a protocol following a femur stress fracture including a load-shedding system quantifiable in percentage permitting to evolve progressively to full body-weight running. While meaningful in the context of ACL-R, the limitations inherent to the swimming pool, unloaded treadmill or load-shedding system (cost, place, maintenance, …) make it difficult to implement in clinical setting. In order to decrease knee loading during RTR, two easy to implement interventions could be done. Increasing step-rate during running is a meaningful running gait modification to decrease knee loading after ACL-R (Bowersock et al., 2017). It could be done by using a running watch or inexpensive wearable devices, listening to music at a specific beat or by using a metronome (Esculier et al., 2020). Running shoe characteristics can also influence loads on the knee (Roth et al., 2016)(Sinclair et al., 2016). The systematic review of Perkins et al.(Perkins et al., 2014) showed that barefoot running or running with minimalist shoes (based on the minimalist index)(Esculier et al., 2015) reduce knee joint contact forces in healthy subjects compared to traditional shoes. Both interventions are likely to prevent knee symptoms exacerbation and facilitate running progression, and are meaningful to be implemented for RTR.

4.4. Limitations

Several limitations of this study should be considered. First, the Running Program Checklist was developed subjectively, and several factors that could affect RTR were not taken into account e.g. warm-up, strengthening exercise … Second, several items were indirectly related; mostly item 9 and 10 ("Where?"(9); "What?"(10)) and items 7 and 8 ("How Much?"(7); "How Much?"(8)). Third, studies included in this review used indistinctly the terms "jogging" and/or "running". Both terms may have different meanings in the articles and a clear definition of these terms is recommended for future research. Fourth, we had not contacted the authors to get additional information limiting our ability to improve on the detail of reporting as initially intended. Finally, this scoping review included studies from the last 10 years and some articles older than 2009 reporting running programs after ACLR were not included.
4.5. Clinical perspectives

Based on the information collected in this scoping review, in clinical guidelines and on our clinical experience, we provide clinical guideline for RTR program in order to improve the rehabilitation process after ACLR (Fig. 3).

5. Conclusion

In view of this serious lack of information concerning running program following ACLR rehabilitation in the literature, further studies are needed to establish a program that includes best evidence and integrates the running program as an essential part of the ACLR rehabilitation.

Conflict of interest and funding

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

Ethical approval

Not applicable.

Ethical statement

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jspt.2022.07.006.

References


