

## Effects of strengthening exercises on the functional recovery of patients undergoing anterior cruciate ligament reconstruction: An integrative review



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### ABSTRACT

**Introduction:** Anterior cruciate ligament (ACL) injury frequently occurs among practitioners of high impact activities and changes in direction, as these individuals have a greater load of tension and develop minor damage to the ligament, which may cause rupture, requiring surgical reconstruction of the ligament. LCA. Decreased strength after reconstruction has been linked to poor function and altered biomechanics, interfering with routine activities of daily living, thus making it impracticable to return to sports activities. **Objective:** To analyze the effectiveness of strengthening exercises in functional recovery after ACL reconstruction. **Methods:** The research is an integrative review based on complete articles published in the last 10 years indexed in PubMed and Portal Periódicos CAPES. The following keywords were used to select the articles: “Anterior Cruciate Ligament Reconstruction” AND “Exercise Therapy”; “Anterior Cruciate Ligament Injuries” AND “Exercise Therapy”. **Results and discussion:** 36 articles were found and 05 selected, where they were unanimous in presenting significantly positive results in the use of exercises in functional rehabilitation after ACL reconstruction. **Conclusion:** It is concluded that exercise therapy is effective for individuals undergoing ACL reconstruction, the improvement in functionality and the return to the practice of routine or sports activities are directly related to exercise therapy.

**Keywords:** Anterior cruciate ligament reconstruction, Exercise therapy, Physiotherapy.

## 1 INTRODUCTION

The knee and its anatomy is one of the very important topics in research involving the human body. It makes up your joint, muscle and ligament formation and are responsible for much of the movements of the lower limbs performed throughout the day. In addition, its joint serves as a support



base that covers the entire weight of the body and also receives load in the practice of some types of physical exercise. The knee has great peculiarity, when we talk about its bone instability, because it is one of the most demanded joints of the human body, capable of sustaining a large amount of load (DE SÁ, D. *et al.*, 2019).

The anterior cruciate ligament (ACL) injury, an injury that is destructive in sports, often occurs among individuals who are practitioners of activities of great impacts and sudden changes of direction, because these individuals have a greater load of tension and develop small damages to the ligament that can cause rupture. Approximately 250,000 ACL injuries have been reported annually in the United States with about 50% of them occurring in the young population of athletes (HUANG, Y. *et al.*, 2020).

Surgical treatment by arthroscopy is the most widely used for the treatment of anterior cruciate ligament (ACL) rupture. The definition of ACL reconstruction surgery (ACLR) with preservation of the remnant involves three distinct procedures grouped under the same nomenclature: selected reconstruction of a single band, preservation of the nonfunctional remnant (NFRP nonfunctional remnant preservation: ACLR in a complete lesion involving both bands with non-functional remnant tissue). The definition of functional or non-functional, relative to the remaining fibers, should be made arthroscopically by palpation with the knee at 90° of flexion and in the neutral position. (LUZO, M. *et al.*, 2016).

However, even after the ACLR is done, it is necessary to act physiotherapeutic, because the Physiotherapist is the professional trained for rehabilitation, it is of fundamental importance to develop dynamic exercises and exercises to strengthen the muscles, which promote symmetrical joint load thus bringing the reduction of abnormal movement patterns. A well-developed postoperative intervention facilitates strength gain without pain and low resistance, being effective in resolving contractures after surgery is essential. Recovering the strength of the muscles that encompass the knee after ACL reconstruction is an essential focus of rehabilitation, decreased strength has been linked to poorer function, altered biomechanics and joint health outcomes interfere directly in routine daily activities (JOHNSTON, P. *et al.*, 2020).

In view of the above, the present study aims to perform an integrative review which addresses the effects of muscle strength exercises on ACL reconstruction.

## 2 MATERIALS AND METHODS

This article is an integrative review. The present review fulfilled five distinct stages of study design, which are inclusion criteria, exclusion criteria, search strategies, study selection and extraction of results. The research inquiry was organized according to the PICO strategy (P -population; I - intervention/area of interest; C – comparison; The –outcomes/outcome. Thus, the following structure was considered: P – Individuals who underwent ACLR; I – Strengthening exercises; O – Functional



recovery of the knee joint. It is noteworthy that, as the present study is an integrative review, the comparison was not used. Consequently, the following question was formulated: Does muscle weakness directly interfere with the recovery of the patient with ACL reconstruction?

The search for potential studies was developed by three independent authors, in the period from September to October 2021. The following electronic databases were consulted: PubMed and Portal Periódicos CAPES. For the selection of articles, the following keywords were used as descriptors: "Anterior Cruciate Ligament Reconstruction" AND "Exercise Therapy" and their corresponding Portuguese. To organize the sample collection, the Boolean operator "AND" was used, and different search strategies were chosen, considering that the databases have different peculiarities and characteristics. These were crossed as follows: "Anterior Cruciate Ligament Injuries" AND "Exercise Therapy"; "Anterior Cruciate Ligament Reconstruction" AND "Exercise Therapy". To select the studies that make up the work, the following criteria were used: studies that were in English and Portuguese; studies that were complete and free; clinical trial and with publication date of the last 10 years (2011-2021). Articles from systematic review, literature, bibliographic, theses and dissertations, publications outside the pre-established search period were excluded.

The analysis of the study was performed descriptively. The ethical principles were preserved, maintaining the copyright of the authors, through the citation of each of them. The studies used were selected according to their eligibility and ineligibility, taking into account the inclusion and exclusion criteria. Next, the authors critically and methodologically analyzed each study found and, finally, the articles were selected for the research.

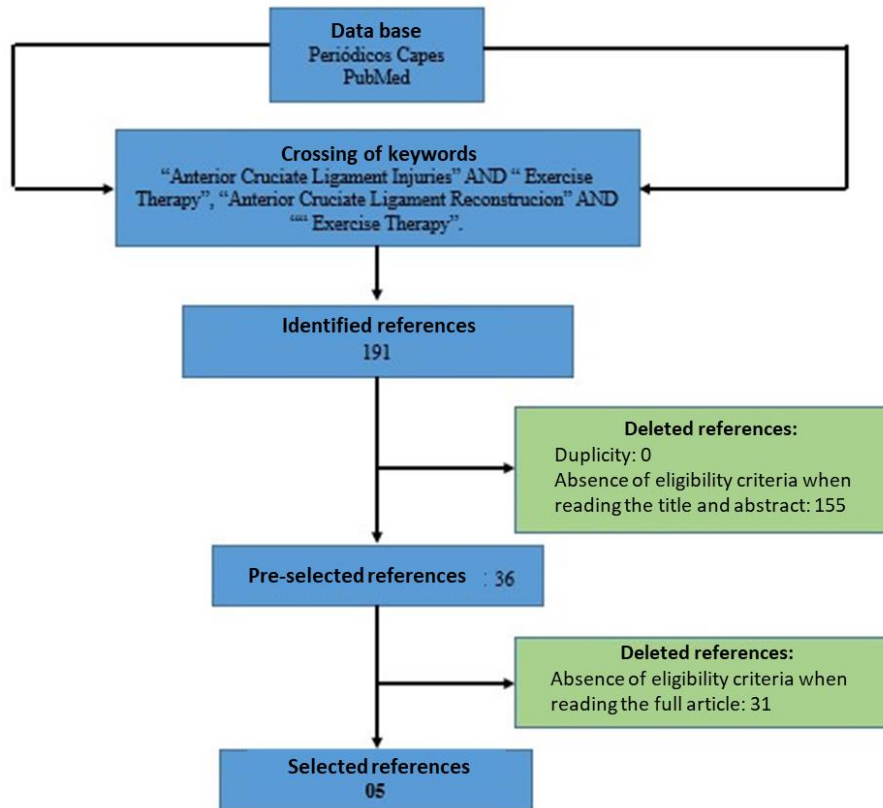
The sum of articles retrieved from the databases was initially screened by reading the titles. Subsequently, duplicate studies were excluded. Subsequently, the titles and abstracts were re-read to verify whether they met the eligibility criteria adopted in this study. As shown in chart 1, those who met the selection criteria were retrieved for reading the full text, a new evaluation regarding the eligibility criteria and extraction of data regarding the author and year of publication, objective, population, methods and outcome.

### 3 FINDINGS

The searches in the selected databases resulted in the identification of 36 articles based on the descriptors used, 19 in PubMed and 17 in the CAPES Periodicals Portal, which were sorted by titles and abstracts. During the reading of the full articles, 31 studies were excluded because they did not agree with the selection criteria adopted. Therefore, 05 studies were eligible to be part of the scope of this integrative review. Figure 1 shows the flowchart with the eligibility stages of the studies.



Figure 1 - Flowchart of the selection of articles (*Prisma Flow*)



Source: Authorial research in the databases PubMed and Portal Periódicos CAPES.

Chart 1 describes the information on the articles selected based on the descriptors used that studied the effects of strengthening exercises on the functional recovery of patients undergoing ACLR.

Table 1: General information of the studies analyzed.

Author/ Year	Goal	Sample	Assessment tools	Treatment protocol	Denouement
FLOSAD OTTIR, V. <i>et al.</i> , 2018	To investigate knee-related self-efficacy 6 years after acute ACL injury in patients treated with exercise therapy alone or in combination with early or late ACLR.	Individual exercises (n = 20). Exercise + early ACLR (n = 46). Exercise + delayed ACL (n = 23).	Knee self-efficacy - K-SES questionnaire (0 to 10) at 6 years.	Exercise therapy alone (n = 20). Exercise therapy plus early ACL (n = 46). Exercise therapy plus delayed ACL (n = 23).	Knee-related self-efficacy 6 years after ACL injury did not differ between those treated with ACLR, performed early or as a late procedure, or exercise therapy only.
LABANC A, L. <i>et al.</i> , 2018	To evaluate the effectiveness of a 6-week training protocol developing NMES along with sitting-to-lift, standing-to-sitting exercises of the quadriceps muscle, as an additional standard rehabilitation	G1 NMES superimposed on STSTS. G2 STSTS only. G3 NAT.	MuscleLab: records muscle strength. Bosco-System Technologies: strength of knee flexors and extensors. Pain: EVA.	2 weeks - continuous passive movement, mobilizations combined with low frequency and high volume of quadriceps NMES.	Participants who underwent electrostimulation + strengthening exercises had higher FM of knee extensors, lower pain perception, and increased symmetry compared to participants who underwent only



	treatment from day 15 to 60 after ACLR.		<p>KISTLER Platforms - Frequency of 100 Hz.</p> <p>15 Hz Butterworth filter - lower end loading symmetry.</p> <p>Tape measure - anthropometric measurements of thigh and knee.</p>	<p>Isometric straight leg lifts by the end of the 1st month.</p> <p>Added squats in the 3-4 weeks, as well as exercises in the water, cycling, walking and stepping.</p> <p>2nd month: strengthening introduced.</p> <p>From the 3rd to the 6th month: progressive muscle strengthening and strength training with relearning of specific sports skills.</p>	exercises or no additional treatment.
ZULT, T. et al., 2018	To investigate whether cross-education, as an adjunct to standard rehabilitation, accelerates recovery of quadriceps strength and neuromuscular function up to 26 weeks after surgery.	<p>EG (n = 22).</p> <p>CG (n = 21) standard rehabilitation.</p>	<p>DI: FM of the quadriceps.</p> <p>Contraction interpolation technique and the central activation ratio (CAR): quadriceps activation.</p> <p>Target matching task, with test-retest: Force control.</p> <p>Joint repositioning task in 4 random positions - 15°, 30°, 45° and 60° of knee flexion: knee proprioception.</p> <p>Static balance test with support of one leg, with eyes open, followed by eyes closed.</p> <p>Dynamic equilibrium test with clockwise stellar execution:</p>	<p>4 weeks: reduce inflammation and swelling, restore full knee extension and facilitate quadriceps activity.</p> <p>4-12 weeks: strengthen the quadriceps and hamstrings with resistance training.</p> <p>12-24 weeks: more advanced balance and core, stability exercises, resistance training with a focus on hypertrophy, running with minimal directional shift, two-legged jumping tasks.</p> <p>24-36 weeks: running with agility exercises, jumping with one leg and strength training focused</p>	Standard rehabilitation improved quadriceps FM, strength control, and dynamic balance in both legs regarding pre-surgery, but adding cross-education did not accelerate recovery after ACLR.



			one-legged balance.	on reducing deficits.  GE: leg press and healthy side leg extension exercise on standard fitness machines.	
PATTERSON, B. <i>et al.</i> , 2021	To determine the feasibility of an RCT by evaluating physical therapist-guided exercise therapy intervention for individuals with persistent symptoms 1 year post-ACLR.	n = 27 (who were 12 to 15 months into reconstruction).	Single jump: maximum distance in front jump.  Side jump: maximum number of jumps in 2 parallel lines in 30s.  Elevation test with one leg.	8 individualized physiotherapy sessions of 30 minutes for 16 weeks.  Exercise program were: 1 - Retraining of the movement; 2 - Strength of the lower limbs; 3 - Balance; 4 - Hip abductor force; 5 - Calf strength; 6 - Trunk strength; 7 - Hip extensor and knee flexor strength; 8 - Cardiovascular exercises.  Each of the eight exercises had three or more difficulty phases for individualized progression.	It is suggested that it is worth proceeding to an RCT evaluating the efficacy of a physiotherapist-guided exercise therapy focused on the lower limbs and educational intervention for young adults who have persistent symptoms 1 year after ACLR.  In addition, beneficial effects of treatment were seen in participants who received the LLLL-focused intervention for symptoms related to knee, function, and QoL.
VIDMAR, M. <i>et al.</i> , 2021	To compare effects of eccentric training and eccentric isokinetic training on quadriceps muscle mass, strength, and functional performance in post-recreational athletes RLCA.	CG* – Conventional group (n = 15).  GI – Isokinetic group (n = 15).	MRI: to evaluate quadriceps muscle mass.  DI: strength.  Lysholm score: functional performance before and after training programs.	6 weeks, 2 times a week, with a minimum interval of 72 h between sessions.  3 or 4 sets of 10 eccentric extensor knee contractions of maximum intensity. 1st mesocycle: weeks 1-3.  2nd mesocycle: weeks 4-6.	It is suggested that training programs exclusively eccentric or containing eccentric overload optimize muscle responses to strength training.

Legend: ACL: anterior cruciate ligament; ACLR: anterior cruciate ligament reconstruction; K-SES: Knee Self-Efficacy Scale; neuromuscular electrical stimulations (NMES); sit-up-sit (STSTS); no additional treatment group (NAT).; Visual Analog Pain Scale (VAS): Visual Analog Pain Scale; FM: muscle strength; EG: exercise group; CG: control group; DI: isokinetic dynamometry; RCT: randomized clinical trial; LLLL: lower limbs; QoL: quality of life; CG\*: conventional group; MRI: magnetic resonance imaging.



## 4 DISCUSSION

In view of the above, the five selected studies showed efficacies in the treatment by exercise therapy, both in group and individualized. To investigate knee-related self-efficacy, Flosadottir, *et al.*, 2018 developed the study with 89 participants, subdividing them into exercises alone with 20 participants, exercise plus early RLCA with 46 participants, and exercise plus delayed RLCA with 23 participants. Knee-related self-efficacy 6 years after ACL injury did not differ between those treated with ACLR, performed early or as a late procedure, or exercise therapy only. It is worth mentioning that one of the limitations of this article is the lack of information about the treatment protocol used, making further comparisons impossible. With the objective of exercise therapy intervention Patterson, *et al.*, 2021 discussed its work with 27 participants, being individuals aged between 18 and 50 years who were 12 to 15 months of reconstruction. His exercise therapy occurred with 8 30-minute individualized physical therapy sessions for 16 weeks. The eight areas in the exercise program were: 1) movement retraining (e.g., landing); 2) lower limb strength (e.g., squatting); 3) balance (e.g., disturbance exercises); 4) hip abductor force; 5) calf strength; 6) trunk strength; 7) hip extensor and knee flexor strength; 8) cardiovascular exercises (e.g., cycling, running, specific sports activities). Each of the eight exercises had three or more difficulty phases for individualized progression. The results of this study suggest that it is worthwhile to proceed to a large-scale RCT evaluating the effectiveness of a lower extremity-focused exercise therapy guided by a physical therapist and educational intervention for young adults who have persistent symptoms 1 year after ACLR. In addition, beneficial effects of treatment were observed in participants receiving the intervention focused on the lower limbs for symptoms related to knee, function, and QoL.

In order to compare eccentric and isokinetic training Vidmar, *et al.*, 2021, analyzed the evolution of 30 male recreational athletes (25 years), randomized to conventional group (CG\*; n = 15) or isokinetic group (GI; n = 15), the therapy occurred lasting 6 weeks, 2 times a week, with a minimum interval of 72 h between sessions. In each training session, participants performed three or four sets of 10 maximum-intensity knee extensor eccentric contractions. First mesocycle: weeks 1-3 and second mesocycle: weeks 4-6. Evidence suggests that exclusively eccentric or overload-containing training programs optimize muscle responses to strength training and the maximum strength production capacity of skeletal muscle is higher during eccentric contraction compared to concentric contraction.

In the studies conducted by Labanca, *et al.*, 2018, 63 RLCA patients were randomly allocated to the electrostimulation treatment group associated with sitting-to-standing position change exercises and vice versa, the treatment group only sitting-to-standing position change exercises, and the group that did not perform any additional treatment, with 21 patients in each group. In the first 2 weeks, the interventions consisted of continuous passive movement, mobilizations combined with low frequency and high volume of NMES of the quadriceps muscles, the intensity of the stimulation was increased



by the trainer in each repetition of each session and throughout all sessions, according to the patient's tolerance, the stimulation lasted 8 s and, 8 s of rest were respected. Later isometric straight-leg lifts and squat exercises, exercises in the water, which involved cycling, walking and stepping were performed until the third month, from there progressive muscle strengthening exercises and strength training together with relearning of specific sports skills were incorporated with a training that lasted from 15 to 60 days and consisted of five sessions per week. Before each NMES session, patients were asked to warm up on a low-resistance exercise bike for 10 min. The result shows that the participants of the electrostimulation group associated with strengthening exercises showed increased muscle strength of the knee extensors, lower perception of pain and increased symmetry compared to participants who underwent only exercises or no additional treatment.

Zult, *et al.*, 2018, carried out a study composed of 43 patients allocated to 22 individuals in the experimental group and 21 in the control group, who received the same standard rehabilitation protocol with the detail that individuals from the control group trained only the injured leg and individuals from the experimental group trained both legs, thus characterizing cross-education. In the first 4 weeks after ACLR, the protocol aimed to reduce inflammation and swelling, restore full knee extension, and facilitate quadriceps activity. Treatment followed with the goals of strengthening the quadriceps and hamstring muscles using resistance training until the 24th week. At weeks 24-36, it was incorporated into the program, running with agility exercises, jumps and strength training, there was a gradual increase in endurance to ensure that patients received an adequate training stimulus, patients were trained twice a week under the supervision of a physical therapist. The experimental group performed the leg press and non-injured leg extension exercise, the exercises consisted of three sets of 8-12 repetitions with 1–2 min of rest between sets. The result in turn shows improvement in quadriceps strength and dynamic balance compared to pre-surgery with the standard rehabilitation protocol, but adding cross-education did not accelerate recovery after ACLR.

## 5 CONCLUSION

It was concluded that exercise therapy was effective for individuals undergoing anterior cruciate ligament reconstruction, providing improved functionality and the return to routine or even sports activities are directly related to exercise therapy. It is worth mentioning that group treatment had an influence on psychosocial factors, especially motivation for exercise, self-confidence, social support and, potentially, knee-related self-efficacy.

In view of the above, further studies are suggested that address the topic of ACL reconstruction and therapy or rehabilitation by exercises, so that the treatment has more and more success and scientific basis, considering that this study will contribute to this, since this is a promising field for further research.





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