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# Effects of strengthening exercises on the functional recovery of patients submitted to anterior cruciate ligament reconstruction: an integrative review

# Efeitos dos exercícios de fortalecimento na recuperação funcional dos pacientes submetidos à reconstrução de ligamento cruzado anterior: uma revisão integrativa

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**ABSTRACT**
Introduction: The lesion of the anterior cruciate ligament (ACL), frequently occurs among practitioners of activities of great impact and changes of direction, because these individuals present a greater load of tension and develop small damages to the ligament that may cause rupture, requiring surgical reconstruction of the ACL. Decreased strength after reconstruction has been linked to poor function and altered biomechanics, interfering with routine activities of daily living, thus making it unfeasible to return to sports activities. Objective: To analyze the efficacy of strengthening exercises in functional recovery after ACL reconstruction. Methods: This research is an integrative review based on complete articles published in the last 10 years indexed in PubMed and Portal Periódicos CAPES. To select the articles the following keywords were used: "Anterior Cruciate Ligament Reconstruction" AND "Exercise Therapy"; "Anterior Cruciate Ligament Injuries" AND "Exercise Therapy". Results: 36 articles were found, and 5 articles were selected. 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 of functionality and the return to routine activities or sports are directly related to exercise therapy.

**Key-words:** Anterior cruciate ligament reconstruction, Exercise Therapy, Anterior Cruciate Ligament Injuries, Physical Therapy.

## 1 INTRODUCTION

The knee and its anatomy is one of the most important subjects in research involving the human body. It comprises its joint, muscle, and ligament formation and is responsible for most of the lower limb movements performed throughout the day. In addition, its articulation serves as a support base that covers all the body weight 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 injury (ACL), an injury that is destructive in sports, often occurs among individuals who are practitioners of activities of great impact and sudden changes of direction, because these individuals have greater stress load and develop minor damage to the ligament can cause rupture. Approximately 250,000 ACL injuries have been described annually in the United States with about 50% of them occurring in the young athlete population (HUANG, Y. *et al*., 2020).

Arthroscopic surgical treatment is the most commonly used treatment for anterior cruciate ligament (ACL) rupture. The definition of remnant preserved ACL reconstruction surgery (RLCA) involves three distinct procedures grouped under the same nomenclature: selected single band

reconstruction, nonfunctional remnant preservation (NFRP nonfunctional remnant preservation: RLCA in a complete injury involving both bands with nonfunctional remnant tissue). The definition of functional or non-functional, relative to the remaining fibers, should be done arthroscopically by palpation with the knee in 90° of flexion and in the neutral position. (LUZO, M. *et al.*, 2016). However, even after the ACLR is performed, physiotherapeutic action is necessary, because the Physiotherapist is the professional trained for rehabilitation, it is of fundamental importance to develop dynamic exercises and muscle strengthening exercises, which promote symmetrical joint load thus bringing about a decrease in 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 strength of the muscles encompassing 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 directly interfere with routine activities of daily living (JOHNSTON,P. *et al.*, 2020).

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

## 2 MATERIALS AND METHODS

This article is an integrative review. This review met five distinct stages of study design, which are inclusion criteria, exclusion criteria, search strategies, study selection, and extraction of results. The search query was organized according to the PICO strategy (P -population; I - intervention/area of interest; C -comparison; O -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 worth mentioning that, since the present study is an integrative review, comparison was not used. Consequently, the following question was formulated: Does muscle weakness directly interfere in the recovery of patients with ACL reconstruction?

The search for potential studies was developed by three independent authors in the period September to October 2021. The electronic databases were consulted: PubMed and Portal Periódicos CAPES. For the selection of articles, the keywords used were: "Anterior Cruciate Ligament Reconstruction" AND "Exercise Therapy" and their correspondents in 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 in the following way: "Anterior Cruciate Ligament Injuries"

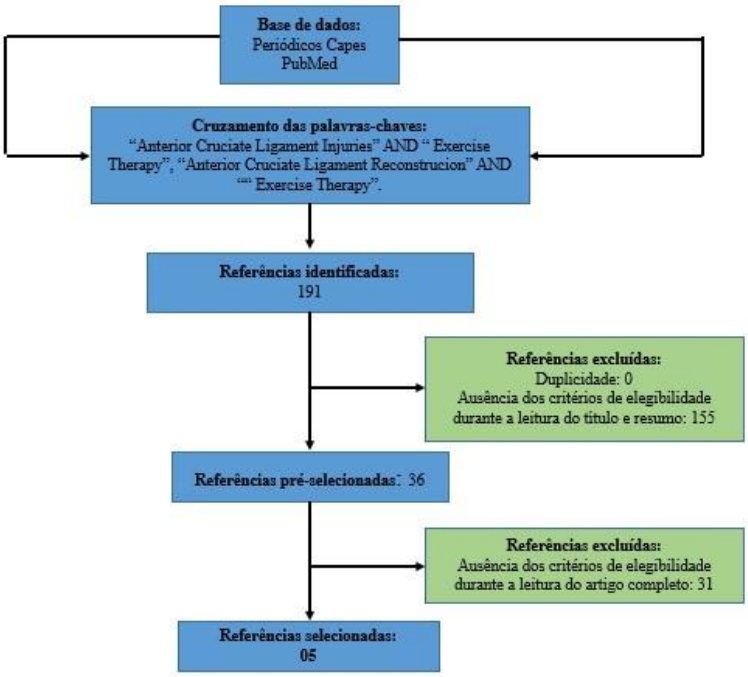
AND "Exercise Therapy"; "Anterior Cruciate Ligament Reconstruction" AND "Exercise Therapy". To select the studies that make up the work, the following criteria were used: studies in English and Portuguese; studies that were complete and free of charge; clinical trial and with a publication date within the last 10 years (2011-2021). Systematic review articles, literature, bibliographic, theses and dissertations, publications outside the pre-established search period were excluded. The study analysis was performed descriptively. Ethical principles were preserved, maintaining the authors' copyrights, by citing each one. 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. Duplicate studies were then excluded. Next, the titles and abstracts were read again to verify whether they met the eligibility criteria adopted in this study. As shown in chart 1, those that met the selection criteria were retrieved for reading of the full text, new evaluation regarding the eligibility criteria, and extraction of data on author and year of publication, objective, population, methods, and outcome.

## 3 RESULTS

The search in the selected databases based on the descriptors used resulted in the identification of 191 articles; the first filtering resulted in 36 articles, 19 from PubMed and 17 from the Portal Periódicos CAPES, which were screened by titles and abstracts. During the reading of the full articles, 31 papers were excluded for not being in accordance 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 study eligibility steps.

Figure 1. Flowchart of the article selection (Prism Flow)




Source: Author search on PubMed and Portal Periódicos CAPES databases.

## 4 DISCUSSION

Chart 1 describes the information about 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 analyzed studies

| Author/ Year | Goal | Sample | Assessment Tools | Treatment protocol | Outcome |
|---|---|---|---|---|---|
| FLOSADOTTIR, V. *et al.*, 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 RLCA. | Individual Exercises (n = 20). Exercise + early RLCA (n = 46). Exercise + delayed RLCA (n = 23). | Knee self-efficacy - K-SES questionnaire (0 to 10) at age 6. | Exercise therapy alone (n = 20). Exercise therapy plus early RLCA (n = 46). Exercise therapy plus delayed RLCA (n = 23). | Knee-related self-efficacy 6 years after ACL injury did not differ between those treated with RLCA, performed early or as a late procedure, or exercise therapy alone. |
| LABANCA, L. *et al.*, 2018 | To evaluate the effectiveness of a 6-week training protocol developing NMES | G1 NMES overlaid on STSTS. G2 only STSTS. | MuscleLab: records muscle strength. Bosco-System Technologies: | 2 weeks - continuous passive movement, combined mobilizations with low frequency and | Participants who underwent electrostimulation + strengthening |

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| | along with sitting to standing, standing to sitting exercises of the quadriceps muscle as an additional standard rehabilitation treatment from day 15 to 60 after RLCA. | G3 NAT. | strength of knee flexors and extensors. Pain: EVA. KISTLER Platforms - Frequency of 100 Hz. 15 Hz Butterworth filter - lower end loading symmetry. Tape measure - anthropometric measurements of thigh and knee. | high volume of quadriceps NMES. Isometric straight leg raises until the end of the 1st month. Squats added in the 3-4 weeks, as well as exercises in the water, cycling, walking and stomping. 2nd month: Strengthening introduced. From the 3rd to the 6th month: progressive muscle strengthening and strength training with relearning of specific sports skills. | exercises showed greater FM of the knee extensors, less perceived pain, and increased symmetry compared to participants who underwent exercises only 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. | GE (n = 22). CG (n = 21) standard rehabilitation. | DI**:** FM of the quadriceps. Contraction interpolation technique and the central activation ratio (CAR): quadriceps activation. Target-matching task, with test-retest: Force control. Joint repositioning task in 4 random positions - 15°, 30°, 45° and 60° knee flexion: knee proprioception. Static balance test with one-legged support, with eyes | 4 weeks: reduce inflammation and swelling, restore full knee extension, and facilitate quadriceps activity. 4-12 weeks: strengthen the quadriceps and hamstrings with resistance training. 12-24 weeks: more advanced balance and core, stability exercises, resistance training with a hypertrophy focus, running with minimal directional change, two-legged jumping tasks. 24-36 weeks: running with agility exercises, one-legged jumping, | Standard rehabilitation improved quadriceps FM, strength control and dynamic balance in both legs compared to pre-surgery, but adding cross education did not accelerate recovery after RLCA. |

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| | | | open, followed by eyes closed. Dynamic balance test with clockwise star running: one-legged balance. | and strength training focused on reducing deficits. GE: leg press and leg extension exercise on the healthy side on standard gym machines. | |
| PATTERSON, B. *et al.*, 2021 | Determine the feasibility of a RCT evaluating physical therapist-guided exercise therapy intervention for individuals with persistent symptoms 1 year post-RLCA. | n = 27 (who were 12 to 15 months into reconstruction). | Single Jump: maximum distance in a forward jump.<br><br>Side Jump: maximum number of jumps in 2 parallel lines in 30s.<br><br>One-legged lift test. | 8 individualized 30-minute physical therapy sessions for 16 weeks. The exercise program was: 1 - Movement retraining; 2 - Lower limb strength; 3 - Balance; 4 - Hip abductor strength; 5 - Calf strength; 6 - Trunk strength; 7 - Hip extensor strength and knee flexor strength; 8 - Cardio-vascular exercises. Each of the eight exercises had three or more difficulty phases for individualized progression. | It is suggested that it is worthwhile to proceed with a RCT evaluating the efficacy of a physiotherapist-guided MMII-focused exercise therapy and educational intervention for young adults who have persistent symptoms 1 year after RLCA. In addition, beneficial treatment effects were seen in participants who received the MMII-focused intervention for knee-related symptoms, function, and QL. |
| VIDMAR, M. *et al.*, 2021 | Compare effects of eccentric training and eccentric isokinetic training on quadriceps muscle mass, strength and functional performance in | CG* - Conventional group (n = 15).<br><br>IG - Isokinetic group (n = 15). | MRI: assess quadriceps muscle mass. DI: strength. Lysholm score: functional performance before | 6 weeks, twice a week, with a minimum interval of 72 h between sessions. 3 or 4 sets of 10 eccentric knee extensor contractions of maximum intensity. | It is suggested that training programs exclusively eccentric or containing eccentric overload optimize muscle |

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| | recreational athletes post RLCA. | | and after training programs. | 1st mesocycle: weeks 1-3. 2nd mesocycle: weeks 4-6. | responses to strength training. |

Given the above, the five selected papers presented efficacies in treatment by exercise therapy, both group and individualized. To investigate knee-related self-efficacy, Flosadottir, *et al,*. 2018 developed the study with 89 participants, subdividing them into exercise 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 RLCA, performed early or as a delayed procedure, or exercise therapy alone. It is worth noting that one of the limitations of this article is the absence of information about the treatment protocol used, making further comparisons impossible.

With the goal of exercise therapy intervention Patterson, *et al,*. 2021 discussed their work with 27 participants, being individuals between the ages of 18 and 50 years who were 12 to 15 months into reconstruction. Their exercise therapy occurred with 8 individualized 30-minute 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., perturbation exercises); 4) hip abductor strength; 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 a large-scale RCT evaluating the effectiveness of a physical therapist-guided lower limb-focused exercise therapy and educational intervention for young adults who have persistent symptoms 1 year after ACLR is worth proceeding. In addition, beneficial treatment effects were observed in participants receiving the lower limb-focused intervention for knee-related symptoms, function, and QL.

Vidmar, *et al,*.2021, analyzed the evolution of 30 male recreational athletes (25 years old), randomized into a conventional group (CG*; n = 15) or an isokinetic group (IG; n = 15). In each training session, participants performed three or four sets of 10 eccentric knee extensor contractions of maximum intensity. First mesocycle: weeks 1- 3 and second mesocycle: weeks 4-6. The evidence suggests that eccentric-only or eccentric overload training programs optimize muscle responses to strength training, and the maximal force production capacity of skeletal muscle is higher during eccentric compared to concentric contraction.

In the studies conducted by Labanca, *et al*,.2018, 63 RLCA patients were randomly allocated into 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 vice versa and, 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, combined mobilizations with low frequency and high volume 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. Subsequently isometric straight leg raises and squatting exercises, exercises in the water, which involved cycling, walking and stepping were performed until the third month, thereafter progressive muscle strengthening exercises and strength training together with relearning 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, the patients were asked to warm up on a bicycle ergometer with low resistance for 10 min. The result shows that participants in the electrostimulation group associated with strengthening exercises showed increased muscle strength of the knee extensors, less perceived pain, and increased symmetry compared to participants who underwent only exercises or no additional treatment.

Zult, *et al*,.2018, conducted a study composed of 43 patients allocated into 22 individuals in the experimental group and 21 in the control group, who received the same standard rehabilitation protocol with the detail that individuals in the control group trained only the injured leg and individuals in the experimental group trained both legs, thus characterizing cross education. In the first 4 weeks after RLCA, 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 ischiotibial muscles using resistance training until week 24. In weeks 24-36, running with agility exercises, jumping, and strength training were incorporated into the program, there was a gradual increase in resistance to ensure that the patients received an adequate training stimulus, the patients were trained twice a week under the supervision of a physical therapist. The experimental group performed leg press and uninjured leg extension exercise, the exercises consisted of three sets of 8-12 repetitions with 1-2 min rest between sets. The result in turn shows improved quadriceps strength and dynamic balance compared to pre-surgery with the standard rehabilitation protocol, but adding cross education did not accelerate recovery after RLCA.

## 5 CONCLUSION

It was concluded that exercise therapy was effective for individuals submitted to reconstruction of the anterior cruciate ligament, 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 showed influence on psychosocial factors, especially motivation to exercise, self-confidence, social support, and potentially knee-related self-efficacy. In view of the above, we suggest further studies that address the subject of ACL reconstruction and exercise therapy or rehabilitation, so that the treatment may have more success and scientific basis, considering that this study will contribute to that, for this is a promising field for further research.

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