

Strength Training Applied To Knee Rehabilitation After Anterior Cruciate Ligament Injury: Integrative Review

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Abstract:

Anterior cruciate ligament (ACL) injuries occur more frequently in daily activities, both in everyday life and sports. The present study aimed to investigate the effects of strength training in the rehabilitation of the knee following anterior cruciate ligament (ACL) injury. An integrative review was conducted in the months of April to May 2023, with a temporal delineation from January 2018 to December 2022. The search was performed in secondary databases, the Virtual Health Library, such as (SCIELO), (LILACS), and (MEDLINE). Article selection was carried out using the following descriptors, generated through the Health Sciences Descriptors (DeCS) platform, in the Medical Subject Headings (MeSH), and employing boolean operators "AND" and "OR": Knee Injuries AND Strength Training AND Anterior Cruciate Ligament Injuries AND Rehabilitation OR Exercise Therapy. A total of 145 publications were identified, and after applying inclusion and exclusion criteria, 8 studies were deemed eligible. The study demonstrated that while strength training with eccentric overload showed greater muscle hypertrophy, potentially beneficial for increasing muscle mass in athletes, it could result in a less favorable muscular phenotype for rapid and explosive movements crucial in certain sports activities. In conclusion, long-term research, evaluation of specific performance variables, direct comparisons between training methods, personalized adaptation, and multidisciplinary interventions are suggested to optimize post-ACL injury recovery.

Key Word: Knee injuries; Strength Training ; Anterior Cruciate Ligament Injuries ; Rehabilitation ; Exercise Therapy.

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I. Introduction

The knee is a intricate joint in the human body, formed by the bones of the shin, patella, and femur. These bones are connected by two tibiofemoral joints (medial and lateral) and patellofemoral joints that facilitate joint movement (Gomes, 2022). Located in the lower extremity, the knee joint plays a crucial role in supporting the human body, requiring a certain degree of stability provided by the muscles and ligaments of the joint (Cardoso, 2021).

In this understanding, the knee is one of the joints with a higher risk of ligament injuries, situated between two large lever arms, the femur and the tibia, and consequently exposed to a greater number of rotational forces. Ligaments play an essential role in maintaining the balance of the knee in response to external forces. Ligaments can act individually or in conjunction with various ligaments, which complicates the study of the fundamental reasons behind the injury (Soares et al., 2023).

When it comes to the knee, ligaments are primarily responsible for the immobility of the joint. The Anterior Cruciate Ligament (ACL) is particularly crucial in this regard and accounts for 50% of musculoskeletal

injuries. Many of these injuries require surgical procedures, such as meniscus restoration surgery and anterior cruciate ligament reconstruction surgery (Li et al., 2023).

Among the structures most prone to injuries in sports activities, especially team sports, and high-intensity activities, the Anterior Cruciate Ligament (ACL) stands out in the knee joint. Its rupture can be caused by rotational movements around its axis, as well as external forces and high demand on the joint during activities that involve cutting and pivoting (Ramos et al., 2022).

Among the qualifications of this ligament, its primary function is to provide stability to the knee, preventing anterior displacement of the tibia in relation to the femur. Its main role is to avoid displacement, and any rupture alerts to this, as it alters arthrokinematics and allows subluxation, manifested through "giving way" (Santana; Mata, 2022).

Anterior cruciate ligament (ACL) injuries occur more frequently in daily activities, both in everyday life and in sports. Rotational, rapid, slow, and sudden stops on the knee joint can lead to ligament rupture, transforming instability into functional impairment and pain, ultimately affecting the quality of life and movement during work activities (Soares et al., 2023).

One of the well-known effects after anterior cruciate ligament surgery is residual deficits in the strength and size of the knee extensor muscle, with links to poor biomechanics, reduced limb function, a high risk of osteoarthritis, and recurrence of injury upon returning to sports. The graft harvesting site also becomes a point of attention, with the final width being checked after extension (Jun et al., 2022).

In this context, strength training has been employed in the treatment of post-surgical ACL injuries, contributing to patient recovery. Strength training, commonly known as weightlifting, is one of the main modalities practiced worldwide. Currently, there is a noticeable increase in awareness regarding body care and overall health maintenance. According to the Ministry of Health, in 2018, there was a 50% increase in the Brazilian population engaged in weightlifting compared to 2006 (Gomes, 2022).

Strength training can help both men and women maintain a healthy body composition by preserving or increasing lean body mass and reducing body fat percentage. Strength training offers various benefits to practitioners and can be a determining factor in decreasing body fat percentage, maintaining health, and promoting a healthier lifestyle, even in the recovery from injuries such as anterior cruciate ligament (ACL) injuries (Jordão et al., 2022).

According to Nogueira et al. (2022), rehabilitation is the process of reintegrating the patient into activities they were previously engaged in. The rehabilitation process, combined with strength training, aims to improve and recover from an injury, facilitating a seamless return to activity without pain. The primary goals of knee rehabilitation in weightlifting include dynamic stabilization of the joint and specific strengthening of associated muscles to restore normal knee movement. Additionally, rehabilitation programs aim to return the patient to their pre-injury condition, incorporating preventive measures to minimize the likelihood of injury recurrence.

The motivation for conducting this study arose from experiences in weightlifting rooms, envisioning different approaches used by sports professionals in ACL injury rehabilitation programs. There is evidence that the most common musculoskeletal disorder affects the knee, with approximately 4.8% (48 per 1,000 patients) affected. About 9% of knee injuries involve the anterior cruciate ligament (ACL). In over 70% of cases, the injury is caused by non-contact mechanisms, such as sudden deceleration, change of direction, or twisting and/or nearly straight knees upon landing back on the surface (Zhang et al., 2022).

Therefore, this study contributes to existing research on the topic, aiming to draw attention from the scientific community to the importance of discussing ACL injuries in the knee and proposing improvements in evidence-based practices for addressing this pathology. Based on the above, the present study aimed to investigate the effects of strength training in the rehabilitation of the knee following anterior cruciate ligament (ACL) injury.

II. Material And Methods

The type of methodology chosen for the present study was the integrative literature review. According to Souza, Silva, and Carvalho (2017), this method has the potential to build knowledge, leading to well-founded and uniform understanding. Additionally, it can overcome some obstacles in the use of scientific knowledge, providing more accessible research results. This is because it allows the reader to access a single study containing a selection of various conducted research, facilitating the swift dissemination of knowledge.

The guiding question for this study was formulated using the PICO Strategy (acronym for P: population/patients; I: intervention; C: comparison/control; O: outcome). In this context, P represented strength training practitioners, I denoted anterior cruciate ligament (ACL), C referred to the knee, and O represented treatment. Consequently, the question posed was: What is the importance of strength training for the treatment of individuals post anterior cruciate ligament (ACL) injury in the knee? The search for publications was conducted in April and May 2023. The temporal scope covered January 2018 to December 2022.

The search was performed in secondary databases, namely the Virtual Health Library, such as Scientific Electronic Library Online (SCIELO), Latin American Literature in Health Sciences (LILACS), and the National Library of Medicine – (MEDLINE). Article selection was carried out through active searching using the following descriptors, developed through the Health Sciences Descriptors (DeCS) platform, in Medical Subject Headings (MeSH), and utilizing boolean operators "AND" and "OR": Knee Injuries AND Strength Training AND Anterior Cruciate Ligament Injuries AND Rehabilitation OR Exercise Therapy.

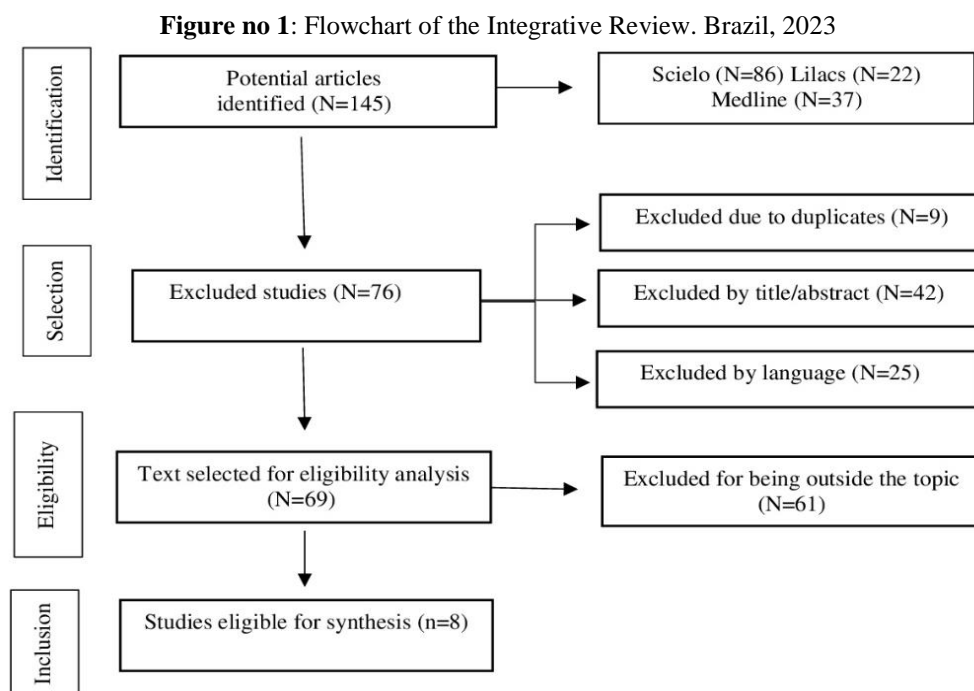
Included in the study were original articles, complete reflections, case studies, systematic reviews, or meta-analyses published in English, Portuguese, or Spanish, between 2018 and 2022. Excluded were incomplete or not freely available publications, studies not involving human subjects, dissertations, theses, or monographs, as well as narrative or integrative reviews. The analysis of the collected material followed the methodology structured by Bardin (2018), which is a technique for qualitative data analysis.

This method consists of the following phases for content analysis: Pre-analysis, Exploration of the material, and Processing, reasoning, and interpretation of the results. The first stage involved organizing the found documents, determining a work scheme with well-defined procedures. It included a floating reading, allowing the initial contact with the documents for analysis, their selection, formulation of hypotheses and objectives, and a detailed description of the indicators guiding the interpretation. For organization, a data collection instrument developed by the author was used.

The second stage covered the exploration of the material, which is the phase of analysis and description. It involved presenting a detailed research corpus under the guidance of hypotheses and theoretical references. This phase consisted of constructing coding operations, cutting texts into record units, defining counting rules, and classifying and aggregating information into symbolic or thematic categories.

The third stage comprised the treatment of results, interpretation, which involves capturing both manifest and latent content in all collected material. The analyzed information is summarized and emphasized to produce explanations and conclusions. This stage is a moment of intuition, reflection, and critical analysis.

In the conducted search, a total of 145 articles were found, with 86 articles in the Scielo database, 22 in the Lilacs database, and 37 in Medline. Of these, 76 studies were excluded, including 9 duplicates, 42 based on title and abstract analysis, and 25 due to being in a language other than the specified ones. This left 69 studies included for eligibility analysis. During this process, 61 studies were excluded for not addressing the objectives or being outside the theme. Consequently, 8 studies were included for the synthesis of this integrative review, as illustrated in the flowchart below.



Source: Author's own work (2022)

III. Result

The presentation of the results is divided into two parts. The first part is related to the characterization of the studies, while the second part focuses on the analysis of scientific production regarding strength training for the treatment of individuals post anterior cruciate ligament (ACL) injury in the knee. From the analysis of the results, relevant variables were established to observe the scientific productions related to the research, as described in Table 1.

Table no 1: Distribution of Scientific Productions According to Database, Year of Publication, Methodological Approach, Geographical Region, and Journals (N = 08). Brazil, 2023.

VARIABLES	N	%
Data base		
LILACS	3	25%
SCIELO	0	00%
MEDLINE	5	75%
Year of Publication		
2018	1	10%
2019	3	40%
2020	2	20%
2021	2	20%
2022	0	0%
Methodological Approach		
Qualitative	1	10%
Quantitative	7	90%
Language		
Portuguese	1	10%
Ingles	7	90%
Spanish	0	0%
Geographic Region		
U.S	4	50%
Brazil	2	25%
UK	2	25%
Periodical		
Rev. Medicine & Science in Sports & Exercise	1	10%
Rev. Brasileira de Fisioterapia	1	10%
Rev. The Physician and Sportsmedicine	1	10%
Rev. Sports Medicine	1	10%
Rev. The American Journal of Sports Medicine	2	40%
Rev. Rev Bras Med Esporte	1	10%
Rev. Jornal Europeu de Fisiologia Aplicada	1	10%

Source: Author's own work (2023)

It can be observed that the majority of studies were identified in Medline with 5 articles (75%), followed by Lilacs with 2 (25%). The year 2019 had the highest number of publications with 3 (40%). Regarding the methodological approach variable, the main approach was quantitative with 7 (90%). In terms of language, English was the predominant language with 7 (90%) articles, and the region with the most studies was the United States with 4 (50%). The primary journal was The American Journal of Sports Medicine, accounting for 40%.

Table 2 provides a synoptic summary of the selected studies for the review, including the identification of articles by authors and year, objectives, study methods, and conclusions found.

Table no 2: Presentation of the articles included in the integrative review, Brazil, 2023

AUTHOR/ YEAR	OBJECTIVE OF THE STUDY	METHODOLOGY	CONCLUSION
Friedmann <i>et al.</i> 2018	The objective of this study was to evaluate whether quadriceps strength training with eccentric overload (CON/ECC +) is more efficient in inducing muscle regeneration after ACL-R than conventional concentric/eccentric strength training (CON/ECC).	Experimental study Progressive resistance training was performed twice a week (Monday and Thursday or Tuesday and Friday, respectively) for 12 weeks (55 men, 13 women)	CON/ECC+ leads to significantly greater muscle hypertrophy compared to CON/ECC, but without the hypothesized effect of increasing SC activation. At the same time, CON/ECC+ induces a slower muscle phenotype less favorable for strong and fast movements.
Vidmar <i>et al.</i> 2019	To compare the effects of conventional eccentric training (constant load) and isokinetic eccentric training on quadriceps muscle mass, strength and functional performance in	Randomized controlled study Thirty male recreational athletes (25 years old) undergoing ACL reconstruction received a standard rehabilitation	Isokinetic eccentric training promotes greater responses than conventional eccentric training in quadriceps muscle mass and strength in recreational athletes after ACL reconstruction.

	recreational athletes after anterior cruciate ligament (ACL) reconstruction.	program.	
Hughes <i>et al.</i> 2019	To compare the effectiveness of BFR-RT and standard-of-care traditional heavy load resistance training (HLRT) in improving skeletal muscle hypertrophy and strength, physical function, pain, and effusion in patients with ACL after surgery.	Randomized, controlled clinical trial study. 28 patients.	Blood flow restriction resistance training can improve skeletal muscle hypertrophy and strength in a similar way to resistance training, with a greater reduction in knee joint pain and effusion, leading to greater overall improvements in physical function.
Forrester <i>et al.</i> 2019	To evaluate the variability of publicly available pediatric anterior cruciate ligament (ACL) reconstruction rehabilitation protocols produced by academic departments of orthopedic surgery and children's hospitals.	Cross-sectional field research	The study suggests that standardizing pediatric ACL reconstruction rehabilitation has the potential to further optimize patient care.
Jung; Choi; Shin, 2020	To examine the effect of core muscle strengthening on lower limb joint kinematics and muscle activations of selected trunk and lower limb muscles during side cutting.	Randomized controlled study 48 male participants	Core strength training altered the motor control strategies and joint kinematics of the trunk and lower extremity, increasing the trunk flexion angle, the VM:VL activation ratio and the H:Q activation ratio and reducing valgus of the trunk. knee and hip adduction angles
Brown <i>et al.</i> 2021	To evaluate whether FRT could serve as a viable method to improve knee strength and function after ACLR.	Case study 15 year old male patient	This case study confirms the feasibility of an 8-week FRT intervention to improve knee strength and function after ACL.
Shu;Han ; Yang, 2021	Observe the Effect of Early Comprehensive Rehabilitation Training on Recovery of Knee Function After Anterior Cruciate Ligament Reconstruction	Randomized controlled study 40 patients	Systematic rehabilitation training can reduce pain and swelling and improve knee joint function after operation.
Minshull <i>et al.</i> 2021	Investigating the Effects of Cross Education (CE) Exercise on Strength and Performance 10 and 24 Weeks After Anterior Cruciate Ligament (ACL) Surgery	Randomized clinical trial. N = 44 patients undergoing ACL reconstruction	High-intensity CE strength training attenuated the postoperative decline in QPF and should be considered in the early phase of ACL rehabilitation.

Source: Author's own work (2022)

It is observed that the majority of publications are randomized controlled trials (RCTs), and such a design represents a cornerstone in scientific research, playing a fundamental role in assessing the efficacy and safety of medical, pharmaceutical, and various other interventions. This methodology is widely used due to its ability to provide reliable and unbiased results.

Randomized Controlled Trials are a powerful tool in scientific research, offering reliable evidence regarding the effectiveness and safety of interventions. Their objective, randomization-based approach makes them essential in clinical decision-making, health policy formulation, and the advancement of scientific knowledge in various fields. However, it is crucial to address their challenges and limitations carefully to continue improving evidence-based research and practice.

IV. Discussion

The information provided in the categories "Comparison of training and its implications for knee function" and "Postoperative ACL rehabilitation" were based on Minayo thematic analysis (2001). Through this perspective, it was possible to identify the main aspects related to training and rehabilitation after ACL reconstruction. Minayo's (2001) thematic analysis made it possible to understand the different training approaches, their implications for knee function and the crucial stages of postoperative rehabilitation.

Comparison of training and its implications on knee function

The study by Friedmann *et al.* (2018), highlights that strength training with eccentric overload results in significantly greater muscle hypertrophy compared to conventional concentric/eccentric training. Although hypertrophy is greater, it is important to note that the resulting muscle phenotype may be less favorable for strong, fast movements, which may have implications for knee function during sporting activities.

The research by Vidmar *et al.* (2019), focuses on isokinetic eccentric training and its effectiveness in improving quadriceps muscle mass and strength after ACL reconstruction in recreational athletes. The results show that isokinetic eccentric training can be an effective approach to optimize muscular and functional recovery after ACL reconstruction surgery.

The Hughes *et al.* (2019), points out the benefits of resistance training to blood flow restriction in postoperative ACL rehabilitation. Resistance training to blood flow restriction has been associated with improvements in muscle hypertrophy and strength, reduced pain and effusion in knee joints, providing a promising therapeutic option to accelerate postoperative recovery.

When comparing the aforementioned studies, it can be seen that different training approaches have specific benefits and may be more suitable for certain contexts. Eccentric overload strength training, for example, can lead to greater muscle hypertrophy, which may be beneficial for certain athletes looking to increase their muscle mass (Hughes *et al.*, 2019; Vidmar *et al.*, 2019; Friedmann *et al.*, 2018).

However, according to Forrester *et al.* (2019), it is important to consider that this greater hypertrophy may result in a muscle phenotype that is less favorable for fast and explosive movements, which may have implications for knee function during sporting activities that require these types of movements. On the other hand, isokinetic eccentric training has been shown to be effective in muscular and functional recovery after ACL reconstruction.

That kind of training for Jeong; Choi; Shin (2020), may be especially relevant for athletes who have undergone this surgery and wish to optimize their recovery and return to sport. Furthermore, blood flow restriction resistance training has also demonstrated benefits in postoperative ACL rehabilitation, such as improvements in muscle hypertrophy and strength, reduced pain and effusion in the knee joints.

It is important to emphasize that choosing the appropriate training must take into account individual objectives, the specific needs of the athlete and the recommendations of professionals in the field, such as physiotherapists and sports coaches. Each approach has its advantages and limitations, and it is critical to personalize the training program to obtain the best results in terms of knee function and performance (Brown *et al.*, 2021).

Comparing different trainings and their implications for knee function highlights the importance of considering individual goals, specific characteristics of the injury or surgery, and professional recommendations when developing an appropriate training program (Minshull *et al.*, 2021). This way, it is possible to maximize the benefits of training and promote effective recovery, improving knee function during sporting activities (Jeong; Choi; Shin, 2020).

Postoperative ACL rehabilitation

For Forrester *et al.* (2019), the importance of standardizing pediatric rehabilitation after ACL reconstruction. Standardization of rehabilitation is crucial to ensure the consistency and effectiveness of treatment, thus optimizing rehabilitation results in children and adolescents who have undergone this surgery.

Otherwise Jeong's study; Choi; Shin (2020), focuses on core strength training and its effects on motor control strategies and joint kinematics during side cutting. The results show that core strength training can improve knee function during specific movements such as side cutting, which is particularly relevant for athletes who rely on this skill in their sports.

Likewise, the study by Brown *et al.* (2021), highlights the FRT (Functional Rehabilitation Training) method as a viable approach to improving knee strength and function after ACL reconstruction. FRT involves specific functional exercises that aim to restore the biomechanical integrity of the knee, thereby improving the individual's ability to return to sporting and functional activities.

For Shu; Han; Yang (2021), systematic rehabilitation training is effective in reducing pain, swelling and improving knee joint function after ACL reconstruction. Systematic rehabilitation, including specific exercises for muscle strengthening, mobility, and joint stability, plays a fundamental role in successful ACL recovery.

Likewise Minshull *et al.* (2021), show that high-intensity strength training after ACL surgery helps to mitigate the decline in physical function. High-intensity strength training, when implemented early in the rehabilitation phase, can help preserve muscle strength and improve physical function, contributing to a faster, more complete recovery.

Postoperative ACL rehabilitation is a crucial process for recovery and safe return to sporting activities after ligament reconstruction. The main objective of rehabilitation is to restore stability, strength and function of the knee, in addition to preventing complications and recurrences (Jeong; Choi; Shin, 2020).

According to Hughes *et al.* (2019), the rehabilitation process is generally divided into different phases, each with specific objectives. In the initial phase, the focus is on reducing pain, controlling swelling and regaining range of motion. Gentle muscle strengthening exercises can also be started. Otherwise, according to Vidmar *et al.* (2019), as the patient progresses in rehabilitation, the emphasis shifts to muscle strengthening,

including the quadriceps, hamstring muscles, and knee stabilizing muscles. Functional exercises such as squats, jumping and controlled running are introduced gradually to improve the dynamic stability of the knee.

For Friedmann *et al.* (2018), as knee strength and stability improve, more advanced exercises are incorporated, such as proprioceptive (balance) training and specific sports activities. The ultimate goal of rehabilitation is to allow the patient to return to sporting activities with safety, confidence and optimized performance.

Brown *et al.* (2021), emphasize that postoperative ACL rehabilitation must be personalized according to the individual needs of each patient, considering factors such as age, level of physical conditioning and type of sporting activity practiced. Furthermore, collaboration between the patient, physiotherapist and surgeon is essential to ensure a successful recovery.

V. Conclusion

The present study demonstrated several training approaches for post-anterior cruciate ligament (ACL) injury rehabilitation. While strength training with eccentric overload has demonstrated greater muscle hypertrophy and may be beneficial for increasing muscle mass in athletes, it may result in a muscle phenotype that is less favorable for fast and explosive movements, crucial in some sporting activities. On the other hand, isokinetic eccentric training and blood flow restriction resistance training have been shown to be effective in muscle and functional recovery after ACL surgery.

Each approach has specific advantages, with isokinetic eccentric training especially relevant for athletes who want to optimize their recovery after ACL surgery. Additionally, blood flow restriction resistance training offers significant benefits in reducing knee joint pain and effusion.

It is crucial to highlight the importance of personalizing the training program, considering individual objectives, the specific needs of the athlete and recommendations from professionals, such as physiotherapists and sports coaches. Standardization of post-ACL surgery rehabilitation is vital, especially in younger patients, to ensure consistency and effectiveness of treatment to optimize results.

The ACL postoperative rehabilitation phase goes through different stages, from reducing pain and swelling to more advanced exercises, focused on muscle strengthening, balance, and finally, specific sports activities. Personalizing the program is essential, considering the age, level of physical fitness and type of sporting activity practiced by the patient. Long-term research, evaluation of specific performance variables, direct comparisons between training methods, personalized adaptation and multidisciplinary interventions are suggested to optimize post-ACL injury recovery.

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