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A systematic review regarding post-operative rehabilitation following anterior cruciate ligament (ACL) injuries in performance athletes

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Abstract

Background. How patients are rehabilitated following anterior cruciate ligament (ACL) surgery has changed significantly in the last years. Clinicians have shifted from extreme immobilization and no muscle activity to minor ROM limits and rapid muscle activation after surgery.

Aims. This study aims to examine the post-operative healing of anterior cruciate ligaments in competitive athletes, emphasizing novel and established methodologies, techniques, and procedures in the literature through a systematic review.

Methods. Following the recommendations established by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) organization, this systematic review was carried out during the months of November 2021 and June 2022. The databases PubMed, Physiopedia, and Google Scholar, were used in this study.

Results. After going through the evaluation process, we discovered that out of the 44 initially retrieved papers, we eliminated around 30 for various reasons, leaving 14 articles that were suitable for the study.

Conclusions. The pre-operative phase plays an essential role in post-operative ACL recovery, acting synergistically with the post-operative phase to accelerate the healing process after surgery and permit more remarkable rehabilitation of lost functions.

Keywords: Post-operative rehabilitation, anterior cruciate ligament, athletes, injuries.

Introduction

It is essential to take precautions while treating *sports injuries* since the types of injuries that might occur in sports depend on the mechanism and circumstances of the event. Since many people play team sports like football, handball, and basketball, e.g., it is only natural that a significant number of people become hurt while participating in these activities. As a result of the intense use of the lower limbs, particularly the knee, in certain sports, it is expected for the knee to sustain the majority of injuries, most of which involve the anterior cruciate ligaments. As a result, there has been an increase in the demand for surgical treatment and post-operative recovery of anterior cruciate ligaments.

The physiotherapist, the sports physician, and the orthopedic surgeon have unquestionably collaborated in the development of the area of *rehabilitation after sporting injuries* in the contemporary world. Under adequate direction, suitable and well-timed *surgical interventions*, and judicious use of pharmaceuticals, the essential components of successful sports trauma rehabilitation treatments are applied to cutting-edge rehabilitation techniques. Injury-specific rehabilitation regimens are employed globally, but they must also be tailored to the nature of the sport based on the athlete's agility, balance, and proprioception levels (Sopa, 2015; Sopa & Szabo, 2015; Sopa & Pomohaci, 2016; Szabo et al., 2020a; Szabo

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et al., 2020b; Szabo et al., 2021). In the developing world, psychological support and a thorough grasp of the athlete's recovery procedures are often missing, though not always (Christakou & Lavallee, 2009).

Physical therapy, which has been shown to be essential for both surgical and non-surgical recovery, is still the most effective intervention that clinicians prescribe to patients to regain strength, range of motion, and patient satisfaction (Bogunovic & Matava, 2013; Paterno, 2017; Filbay & Grindem, 2019; Paterno et al., 2019), which is and interesting finding. In recent years (Filbay & Grindem, 2019; Paterno et al., 2019; Andrade et al., 2020; Forrester et al., 2019), a substantial amount of research effort has been directed toward the optimization of physical rehabilitation regimens for patients who have undergone surgical procedures as well as for those who have not. To be more specific, the time, length, number of treatment modalities, and aims of therapy have all been the subject of much discussion, and alternatives have been rapidly expanding (Forrester et al., 2019; Giesche et al., 2020; Balki et al., 2016; Wright et al., 2019; Jenkins et al., 2022).

In recent years, many studies have asked if the attempt to align any knee mechanically may create specific issues connected to ligament imbalance. These concerns might explain the almost 20% incidence of unsatisfied patients, as emphasized in some papers. Indeed, the patient and the surgeon have different expectations regarding the post-operative period; nevertheless, we need to keep in mind that there is a significant difference between normal knee kinematics, prosthetic knee kinematics, and arthritic knee kinematics. Recent advances in knee surgery have led to the development of a technique known as kinematic alignment, which aims to enhance patient knee function and pain management while reducing any surgical gesture focused on ligament balance. The clinical findings demonstrate that it is a method of measuring bone excision, which is crucial to establish good kinematic alignment (Schiraldi et al., 2016).

After having surgery on their anterior cruciate ligament (ACL), patients have undergone considerable changes in the manner in which they are rehabilitated throughout the course of the previous several decades. During this time, physicians have progressively shifted their approach, moving away from complete immobilization and avoiding any kind of muscle activity in favor of limited range of motion (ROM) limitations and rapid muscle stimulation after surgery (Beynnon et al., 2005; Keays et al., 2007; Linden et al., 2007; Pinczewski et al., 2007; Risberg et al., 2007). Despite the fact that ACL post-operative rehabilitation has constantly been developing, relatively little published literature is available that outlines the precise nature of *ACL rehabilitation*. The authors of this article have devoted their whole clinical practice to treating knee injuries, and as a result of this concentration, they have devised a novel approach to ACL rehabilitation called the Knee Symmetry Model (Biggs et al., 2009).

A damaged ACL almost always requires surgical restoration before an athlete may go back into competition. However, the findings of a recent systematic study indicated that only sixty per cent of non-elite athletes could return to the same level of competition they had achieved before their injuries after undergoing ACL repair. *Post-operative rehabilitation* needs to be started as soon as possible and should be individualized according to the patient's functional features. The primary objective is to return the knee that was operated on to its function level before the accident. Specialized regimens may hasten and improve a person's recovery to their pre-injury level of athletic performance. There is a standard protocol as well as an accelerated protocol. *The accelerated protocol* offers quicker improvement but is often geared toward persons with a high degree of past sports achievement.

Nevertheless, determining whether it is safe to resume athletic activity after having an ACL repair is a crucial choice. There have been a number of different efforts made to identify an appropriate schedule for a return to sport after anterior cruciate ligament surgery, using a range of subjective and objective indicators. These approaches have been successful in some instances; however, none of these attempts has been validated to the extent that is desired (Rambaud et al., 2017; Zduński et al., 2015).

Post-operative recovery of anterior cruciate ligaments arose out of a need, so considerable progress has been made in this area over the last few decades. Sports are being splashed all over the media, thus gaining popularity and becoming an essential source of entertainment for people at home who watch competitions eagerly. This article aims *to discuss the post-operative recovery of anterior cruciate ligaments in competitive athletes, highlighting new and established methods, techniques and procedures in the literature from the perspective of a systematic review.*

Material and methods

This particular systematic review was designed between November 2021 and June 2022 to adhere to the guidelines set by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). PubMed, Physiopedia, and Google Scholar were the databases that were used for this study, and specific search keywords were used as search phrases (Table I):

a) *PubMed*: (anterior cruciate ligament) OR (anterior cruciate ligament reconstruction) OR (athletes return to preinjury sport) AND (rehabilitation) OR (after anterior cruciate ligament reconstruction) AND (male/female athletes) OR (return to sports after anterior cruciate ligament reconstruction);

b) *Physiopedia*: (rehabilitation after ACL reconstruction) AND (male/female athletes) AND (athletes' return to pre-injury sport); OR (anterior cruciate ligament) OR (anterior cruciate ligament repair) AND (return to sports after ACL reconstruction);

c) *Google Scholar*: (reconstruction of the anterior cruciate ligament) OR (athletes returning to their sport after injury) OR (reconstruction of the anterior cruciate ligament) AND (rehabilitation) OR (after reconstruction of the anterior cruciate ligament) AND (male/female athletes) OR (return to sports after anterior cruciate ligament reconstruction).

The records identified from the databases with the key terms mentioned above were saved using the reference manager software *EndNote X9*, which subsequently was used remove the duplicate articles.

Table I
Inclusion and exclusion criteria.

Parameters	Inclusion criteria	Exclusion criteria
Population	Athletes practicing professionally or regularly any sport (even at hobby level); both genders.	People who practice sport irregularly or not at all.
Intervention	Not applicable	
Comparison	Not applicable	
Results	Determining the rate of return to the sport of performance athletes after ACL reconstruction Investigated the effects of strength training protocol on thigh musculature.	Determining the autonomy rate of sedentary people after ACL reconstruction.
Study design	Systematic review, meta-analysis, case-control, cross-sectional studies, literature reviews, case reports. *All articles published after 2009.*	Expert opinions, letters to the editor, and conference reports. *Articles published before 2009.*

Data extraction

From each article selected and included for this review, the following specific information was extracted using an Excel form:

- The primary objective of this study is the post-operative recovery of anterior cruciate ligaments among competitive athletes;
- The main aim is to establish a conclusion on post-operative anterior cruciate ligament recovery protocols among performance athletes;
- Typology of studies reviewed in this paper: systematic review, cross-sectional studies, meta-analysis, case-control, case reports and literature reviews;
- The study sample comprises athletes practicing professionally or regularly, regardless of the gender of the athlete.

Results

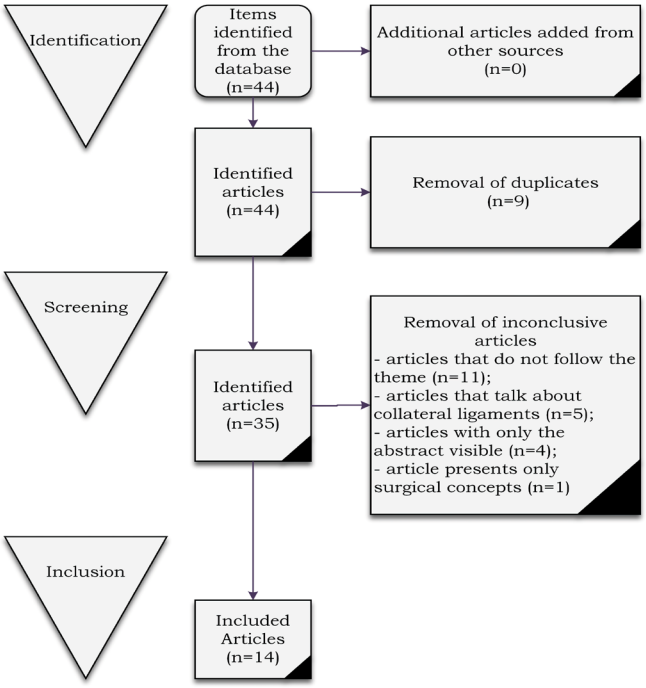

Fig. 1 – Flowchart of the study selection process according to PRISMA guidelines.

Following the first database search, we identified 44 articles possibly suitable for our research. Arriving at the sorting phase, we noticed that:

a) Nine articles were duplicates.
b) Eleven articles did not follow the theme.
c) Five articles dealt with the topic of the collateral ligament.
d) Four articles had only the abstract available.
e) One article presented only surgical concepts.

Following the review process, out of the 44 initially found, we dropped approximately 30 articles for the reasons listed above, leaving 14 eligible articles. Fig. 1 represents the complete PRISMA diagram.

Table II
Details of the identified studies.

Study details			Sample			Results
Reference	Main objective	Main purpose	Gender	n	Level	Results obtained
(Welling et al., 2019)	Effects of a strength training routine on the strength of the quadriceps and hamstring muscles are being investigated.	Football players who have had their anterior cruciate ligaments (ACLs) rebuilt had their strength training outcomes compared.	M	68	Beginner.	Seven months following surgery, the damaged limb's quadriceps and hamstrings were no weaker than those of the dominant leg in the control group.
(White et al., 2013)	Evaluating the effects of neuromuscular training after surgery on knee joint loading, gait biomechanics, and clinical outcome measures for athletes.	Develop future treatment plans to maximise short- and long-run operational consequences following anterior cruciate ligament restoration.	F/M	40 / 40	Performance level.	Subjects receiving accelerated care will demonstrate symmetrical knee joint loading, symmetrical motion patterns, improved clinical and functional outcomes, and improved knee function compared to subjects receiving standard care.
(Lai et al., 2018)	Calculate anterior cruciate ligament graft breakage prevalence and assessment of post-surgical athletic performance.	Estimate the time required to calculate the return to sports rates, calculate graft rupture rates, and anterior cruciate ligament reconstruction, assess post-surgical athletic performance, and identify the determinants of return to sports rates.	M	10	Performance level.	The anterior cruciate ligament graft breakage prevalence was 83%. 5.2% suffered a graft rupture.
(Failla et al., 2016)	Comparison of functional results in a sample that completed further pre-operative therapy two years after ACL surgery. This additional rehabilitation included gradual enhancing and neuromuscular exercise following resolution of deficits.	Two years following ACL replacement, the group that was treated with significant pre-operative rehabilitation would have higher functional results.	F/M	105 / 87	Performance level.	The group that was given different pre-operative therapy, which included neuromuscular training and progressive strengthening, in addition to a criteria-based post-operative rehabilitation program, had higher functional results.
(Grindem et al., 2015)	Comparison of pre- and post-operative patient-reported outcomes (PROs) over a period of two years in patients undertaking progressive pre- and post-operative rehabilitation at athletics medicine hospital as opposed to those receiving conventional treatment.	Recuperation of knee function and muscular strength utilising functional landmarks and repeated testing preoperatively, six months, one year, and two years after surgery.	F/M	1345/ 1429	Intermediate and Performance level.	Two years after surgery, participants in a prospective cohort who had received both standard treatment and progressive rehabilitation at athletics medicine hospital reported better results.
(Kim et al., 2015)	Examining the consequences of a four-week pre-operative training implication on knee toughness and function after surgery.	A pre-operative exercise program would improve post-reconstruction functional outcomes of the anterior cruciate ligament.	M	80	Intermediate level.	Four weeks of pre-operative exercise may have several beneficial consequences after reconstructive surgery, including a quicker recovery of knee extensor strength and function, as indicated by the ability to hop on one leg.
(Shaarani et al., 2013)	The group concluded a six-week exercise program at the gym and at home. Assessments included single-leg examination; quadriceps and hamstring maximum torque cross-sectional area, and magnetic resonance imaging	A pre-operative exercise program would improve post-operative consequences following anterior cruciate ligament reconstruction	M	23	Intermediate level.	Knee function was improved after six weeks of gradual prehabilitation for patients having anterior cruciate ligament repair, as measured by the single-leg hop test and self-assessment using the modified Cincinnati score.
(Zduński et al., 2015)	Restoring as much range of motion as possible in the studied joint, as well as the regular gait pattern, muscle strength and proprioception throughout the limb.	A Lysholm and Gillquist scale investigation of the efficacy of pre-operative physical therapy for patients who will be having arthroscopic repair of the anterior cruciate ligament.	F/M	17 / 13		Patients with total anterior cruciate ligament rupture participating in a pre-operative rehabilitation programme led by a physiotherapist achieved more excellent functional status than the control group.
(Yonetani et al., 2022)	The film dressing would produce improved subjective patient outcomes and decreased post-operative bleeding compared to conventional gauze dressing with bandages.	A comparison of the clinical efficacy of cryotherapy proceeding ACL restoration utilizing two distinct wound dressings: transparent semi-permeable polyurethane film dressings and standard post-operative gauze dressings.	F/M	41 / 19	Beginners.	Film dressing increased the impact of cryotherapy in terms of pain management, wound drainage, and inflammation immediately after surgery in comparison to the usual elastic-coated gauze dressing.
(Hartigan et al., 2009)	Ten physiotherapy sessions were provided to the group. These sessions included gradual quadriceps strength preparation as well as specialised neuromuscular exercises that included the methodical translation of weight-bearing surfaces.	Pre-operative training would help people with anterior cruciate ligament tears who complain of knee instability regain quadriceps strength and walk normally after ligament reconstruction.	F/M	13 / 6	Performance level.	Quadriceps strength indices have improved over time. Disruptive training increases movement and decreases muscle contractions in the involved limb during the weight-bearing phase of walking to potential copers after anterior cruciate ligament reconstruction.
(de Valk et al., 2013)	Single-beam arthroscopic techniques affect post-operative rehabilitation.	Determining patient factors and trauma elements before anterior cruciate ligament reconstruction affects post-operative rehabilitation.	M	40	Performance level.	Better functional outcomes for male patients under 30 years of age patients with anterior cruciate ligament reconstruction within three months of injury and high initial activity level.
(Eitzen et al., 2009)	Determine pre-operative characteristics that may accurately predict how well a knee will function two years after having the anterior cruciate ligament reconstructed.	The essential factor in predicting knee function two years following reconstructive surgery would be pre-operative quadriceps strength.	M	60	Intermediate level.	Pre-operative quadriceps muscle toughness debts and meniscus damages significantly negatively affect long-term functional consequences following anterior cruciate ligament reconstruction.

Study details			Sample			Results
Reference	Main objective	Main purpose	Gender	n	Level	Results obtained
(Lepley & Palmieri-Smith, 2016)	This article discusses the proactive strategy physicians may use before surgery to reduce quadriceps weakness after the procedure.	Exploring the connection between pre-operative and post-operative quadriceps activation in order to better understand the relationships between the two.	F/M	23 / 31	Beginners.	Individuals with a higher level of quadriceps activation before the operation had a higher activation level after the procedure.
(Quelard et al., 2010)	A goniometric measurement of the patient's range of motion was taken one day before surgery and six weeks and three months after the procedure. The pre-operative magnetic resonance imaging revealed that there was some bone bruise (MRI).	Anterior cruciate ligament (ACL) repair may lead to a significant loss of mobility, thus, it's essential to understand what variables could have contributed to this loss before surgery.	F/M	21 / 7	Beginners and intermediate level.	Major risk factors for complicated rehabilitation following ACL repair include a limited pre-operative range of motion as well as characteristic bone bruising of the lateral femoral condyle and tibial plateau.

Discussion

In this section, we will focus on some of the components of this systematic review that relate to the post-operative healing of anterior cruciate ligaments among performance athletes. These ligaments are often injured during athletic competition.

We begin by describing the fundamental goal of this research, which is to identify the approach that will be most successful in reintroducing the athlete to the competitive environment of the professional sports circuit. Concurrently, the emphasis will be placed on regaining lost skills to the greatest extent possible, up to one hundred per cent if possible.

Some authors (Rambaud et al., 2017; Zduński et al., 2015) believe that the athlete performs best following an accelerated recovery plan. This accelerated recovery plan is divided into 3 phases, each with its goals and recommendations. The accelerated recovery phases are a sum of procedures, techniques and methods designed to relieve pain, strengthen joints and give the athlete confidence in their recently operated lower limb because a competitive athlete needs, in addition to a well-developed body, a strong mentality so that they can cope with all the pressure they feel on their shoulders.

After extracting and studying the articles in the literature, which have a common goal and purpose, we have divided the discussions into two broad categories: those related to the pre-operative phase of recovery and those associated with the post-operative phase of recovery:

- During the pre-operative period, this group includes articles which have:

o A common objective (Failla et al., 2016; Grindem et al., 2015; Kim et al., 2015; Eitzen et al., 2009; Lepley et al., 2016; Quelard et al., 2010): they aim at:

- Comparison of functional outcomes at two years following ACL reconstruction in a cohort undergoing additional pre-operative rehabilitation;

- Comparison of 2-year pre-operative and post-operative patient-reported outcomes of patients undergoing progressive pre-operative and post-operative rehabilitation at athletics medicine hospital compared to usual care;

- Examining the consequences of a 4-week pre-operative training implication on knee strength and function after surgery;

- Understanding the counteractive method doctors should utilize preoperatively to reduce post-operative quadriceps weakness;

- Identifying pre-operative predictors of knee function two years following reconstructive ACL surgery.

o A common purpose (Failla et al., 2016; Grindem et al., 2015; Kim et al., 2015; Eitzen et al., 2009; Lepley et al., 2016; Quelard et al., 2010): they aim at:

- Two years following ACL replacement, the group of patients who were treated with significant pre-operative rehabilitation would have better functional results;

- a pre-operative exercise program would improve post-reconstructive ACL functional outcomes;

- a pre-operative exercise program would improve post-operative outcomes after ACL reconstruction;

- determine if there is a correlation between the strength of the quadriceps before surgery and how well the knee functions two years following reconstructive surgery;

- evaluate the efficacy of pre-operative physiotherapy in patients who are scheduled for arthroscopic ACL reconstruction;

- pre-operative training to help people with ACL rupture who complain of knee instability to regain quadriceps strength and walk normally after reconstruction;

- the strongest predictor of knee function two years following reconstructive surgery would be pre-operative quadriceps strength;

- During the post-operative period - this group includes articles which have:

o A common objective (Grindem et al., 2015; Yonetani et al., 2022; de Valk et al., 2013; Lepley et al., 2016): these aims at:

- comparison of 2-year pre-operative and post-operative outcomes reported in patients experiencing enlightened pre-operative and post-operative rehabilitation at athletics medicine hospital compared to usual care;

- film dressing would produce improved subjective patient outcomes and decreased post-operative bleeding compared to conventional gauze dressing with bandages;

- Single beam arthroscopic techniques affect post-operative rehabilitation;

- the counteractive approach that clinicians should use preoperatively to alleviate post-operative quadriceps weakness.

o A common purpose (Grindem et al., 2015; Yonetani et al., 2022; de Valk et al., 2013; Lepley et al., 2016): these aims at:

- comparison of the clinical efficacy of cryotherapy

following ACL reconstruction employing two different wound dressings, conventional gauze dressings postoperatively and transparent semi-permeable polyurethane film dressings;

- comparison of the regaining knee function and muscle strength using functional landmarks and repeated testing before surgery and at six months, one year, and two years postoperatively;

- comparison of the regaining knee function and muscle strength using functional landmarks and repeated testing before surgery and at two years postoperatively;

Conclusions

From all the articles studied to develop this scientific paper, two essential aspects of post-operative ACL recovery among competitive athletes could be emphasized as conclusion:

1. The pre-operative stage plays a significant role in post-operative ACL recovery, which acts synergistically with the post-operative phase to speed up the healing process following the surgical procedure and facilitates a more generous percentage of rehabilitation of lost functions.

2. The second conclusion drawn relates only to the post-operative stage of the anterior cruciate ligament rupture. When talking about this stage, we can list a wide range of processes and procedures used, but the accelerated recovery protocol must be highlighted. The accelerated protocol, unlike the traditional one, is more physically demanding for the patient, but its effects on knee rehabilitation are far superior.

Conflict of interests

Nothing to declare.

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