Physiotherapy management of post-operative ACL Rehabilitation: a cross-sectional survey in Gauteng, South Africa

Colett Robbertse

(0207027T)

A Research Report submitted to the Faculty of Health Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Physiotherapy.

Johannesburg, 2023

Declaration

I, Colett Robbertse, declare that this Research Report is my own, unaided work. It is being submitted for the Master of Science in Physiotherapy at the University of the Witwatersrand, Johannesburg, and it has not been submitted before for any degree or examination at any other University.

Colett Robbertse _____  _____

Name of candidate Signature of candidate

22 day of March 20 23 in Johannesburg

Dedication

I dedicate this research report to my family without whom this would not have been possible.

Abstract

Background**:** There are a variety of protocols used by physiotherapists for post-operative ACL rehabilitation. The study aimed to determine the management strategy and treatment modalities currently used by physiotherapists in post-operative ACL rehabilitation, in Gauteng, South Africa.

Method: The methodology of the study was a quantitative cross-sectional study. A self-designed questionnaire was developed for this study. The questionnaire comprised of three sections: Part 1 which captured the demographic information, part 2 which captured specific questions regarding rehabilitation protocol and part 3 which captured questions about physiotherapy goals and outcome measures. The questionnaire was loaded on the REDcap online survey system. The link with introduction, explanation, ethical approval and consent to participate was sent to the SASP and PASA for distribution to their members. Due to a poor response rate from the participants, the questionnaire was then distributed via social media. The data collection term was from 15 December 2021 up to 27 May 2022.

Results: 120 participants accessed the questionnaire. Only 46.6% of the responses captured could be used for data analysis. The exclusions included 22 incomplete responses and 42 responses from participants not working in Gauteng. The analysis of the survey revealed that there is a great variety of protocols, physiotherapy modalities, exercise prescription and outcome measured used in post-operative ACL rehabilitation by physiotherapists in Gauteng, South Africa.

Conclusion**:** More research about evidence-based protocols, physiotherapy modalities and exercise prescription are required to improve the outcomes of post-operative ACL rehabilitation.

Acknowledgement

A big thank you to Dr V Naidoo for all your help and support to finish this report in the timelines that we did.

Thank you to Seph Robbertse, Nicolette Robbertse and JJ Robbertse for your empathy and patience. Your supply of hot tea and hugs carried me through the last two years.

Contents

List of Tables

List of Figures

List of Appendices

List of Abbreviations

Construct	Abbreviation
Anterior cruciate ligament	ACL
Closed kinetic chain	CKC
Continuous passive movement	CPM
Full weight-bearing	FWB
International Knee Documentation Committee Subjective Knee Evaluation Form	IKDC
Non-weight-bearing	NWB
Mechanical diagnosis and treatment	MDT
Open kinetic chain	OKC
Orthopaedic manipulative therapy	OMT
Partial weight-bearing	PWB
Proprioceptive neuromuscular facilitation	PNF
Physiotherapy Association of South Africa	PASA
Range of Motion	ROM
South African Society of Physiotherapy	SASP
Sport and exercise therapy	SPT
The Knee injury and Osteoarthritis Outcome Score	KOOS
United States of America	USA

List of definitions:

Accelerated protocol is defined as the concept of gaining terminal knee extension immediately following reconstruction, early progressive range of motion (ROM) and early progressive weight-bearing (WB)

Non- accelerated protocol is defined as knee immobilisation for the first 2 weeks, non-weight-bearing (NWB) mobilisation with progression to full weight bearing after 6 weeks post-operatively. Progressive ROM only after the stability of the ACL graft is determined.

Return to normal function in the context of this questionnaire is that the patient has obtained a pre-injury level of function in activities of daily living.

Return to sport in the context of this questionnaire is that the athlete has returned to his or her sport and is performing at or better than the pre-injury level.

Chapter 1 Introduction

1.1 Background

The anterior cruciate ligament (ACL) adds to the movement and stability of the knee joint. “It is an intra-articular ligament found in the knee joint that originates on the inner surface of the lateral femoral condyle superiorly, runs obliquely through the intercondylar fossa and inserts into the middle part of the condylar area of the tibia inferiorly” (Petersen and Tillmann, 2002). The ACL protects the knee from rotational loads and anterior tibial translation during weight-bearing and ROM (Sakane *et al.*, 1999).

ACL injuries are common injuries that effect patients of different age groups and levels of activity (Shea and Carey, 2015). The retrospective study International Epidemiology of ACL injuries by Singh et al (2018) compared the incidence of injury of ACL ligament in the population of different countries. The countries they looked at were the Denmark, Germany, Norway, United States of America (USA), Sweden, and New Zealand. They found that the incidence in the population of these 6 countries fell within 29 to 38 out of 100,000 people annually.

In the literature many intrinsic, extrinsic, modifiable, and non-modifiable risk factors that can contribute to the development of ACL injuries can be found. Some of these risk factors include joint laxity, biomechanics, neuromuscular control, genetics, and previous injury (Mclean, 2007, 2013; Acevedo *et al.*, 2014; Hewett *et al.*, 2016). But even though some or all the factors are present it does not necessarily mean that these patients will injure their ACL. To injure the ACL, a specific event with a specific mechanism of injury must occur (Hewett *et al.*, 2016). The injuries usually occur with hyperextension of the knee or a sudden change in direction while moving in non-contact situations (Mclean, 2007; Boden *et al.*, 2010; Singh, 2018).

Current treatment techniques for ACL injuries include conservative or surgical intervention. Surgical intervention is seen as the current standard clinical treatment after ACL injury (Shea and Carey, 2015). There are various options for surgery after

an ACL injury. The standard surgical management of ACL injuries is arthroscopic reconstruction (Samuelsen *et al.*, 2017).

“Post-operative rehabilitation is a major factor contributing to the success of ACL repair” (Janssen *et al.*, 2018). According to Markatos et al (2013) rehabilitation aims to increase ROM, balance and muscle strength and it should attempt to prevent injury to the graft. There has been some suggestion about specific protocols for post-operative ACL rehabilitation. These include early mobilisation, early WB, no protective bracing and accelerated protocol (Eitzen *et al.*, 2010). However, according to the literature the is no consensus regarding the optimal rehabilitation programme and when patients should return to sport post-operatively (Yabroudi and Irrgang, 2013).

There is some guidance on specific modalities that show positive results when added to existing protocols. These modalities include: cryotherapy, neuromuscular electrostimulation, dry needling, peripheral joint mobilisation, and blood flow restriction (Sakane *et al.*, 1999; Wright *et al.*, 2015; Van Melick *et al.*, 2016; Baron *et al.*, 2020; Giesche *et al.*, 2020).

The aim of post-operative ACL rehabilitation is to return the patient to their highest functional level safely, as soon as possible, and to prevent secondary complications to surrounding ligaments, menisci, and the cartilage of the knee. Statistically, the rehabilitation outcomes currently in the USA show that only 33% of athletes return to participation in sport within one year after ACL injury and 37% never return to prior levels of participation (Greenberg *et al.*, 2018)

1.2 Problem Statement

There are a variety of protocols used by physiotherapists for post-operative ACL rehabilitation. This variety stems from every practice developing their own protocols together with the orthopaedic surgeon they work with as well as their clinical experience, as seen in my experience as a physiotherapist involved in post-operative ACL rehabilitation.

This variety leads to a discrepancy between the empirical evidence of ACL rehabilitation and the literature findings. Similar findings were also found in surveys

done in the USA (Greenberg *et al.*, 2018), Australia (Ebert *et al.*, 2019), New Zealand (Fausett, Reid and Larmer, 2022), Greece (Korakakis *et al.*, 2021) Brazil (Aquino *et al.*, 2021) and Belgium (Dingenen *et al.*, 2021).

This in turn may lead to delayed independent function or return to sport or even cause the patients not to return to sport at all - also noticed in my experience as a physiotherapist involved in post-operative ACL rehabilitation.

1.3 Research Question

Which physiotherapy management protocol, strategies and treatment modalities do physiotherapists use during post-operative ACL rehabilitation?

1.4 Aims

The study aims to determine the management protocol, strategy and treatment modalities currently used by physiotherapists in post-operative ACL rehabilitation, in Gauteng, South Africa.

1.5 Objectives

1.5.1 To determine the number of physiotherapists that use an accelerated and non-accelerated protocol.

1.5.2 To determine the following rehabilitation goals post ACL surgery:

- If rehabilitation starts preoperatively or post-operatively
- The WB protocols
- The frequency of use of protective bracing
- When patients return to normal function
- When patients return to sport

1.5.3 To determine the commonly used physiotherapy management strategies, modalities, and exercise prescription in the first six weeks of post-operative ACL rehabilitation

1.5.4 To determine the outcome measures used in post-operative ACL rehabilitation.

1.6 Significance

With the identification of the most prevalent protocols, management strategies, modalities, exercise prescription and outcome measures used by physiotherapists in practice in Gauteng, a comparison can be made between the results of the survey and the evidence-based practices described in the current literature. This in return will improve the clinical reasoning for treating clinicians and guide possible future research to improve the protocol guidelines for post-operative ACL rehabilitation with the overall aim of improving patient outcomes and success rate of returning to function and sport.

1.7 Outline of this Research Report

Figure 1.1 demonstrates the outlines of the research report.

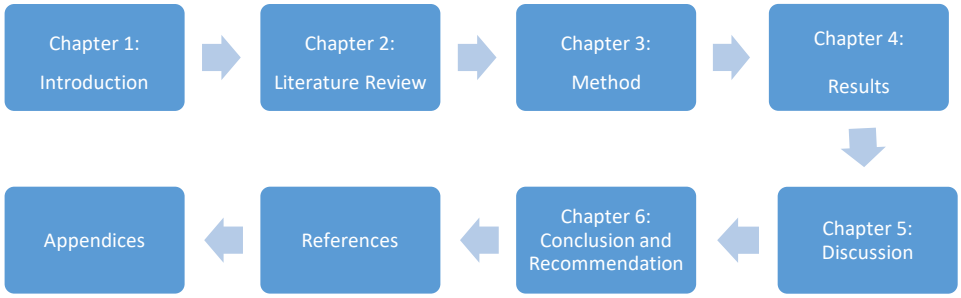

Figure 1.1: Outline of the research report

Chapter one included the research question, aims, objectives and significance of the study. The literature review will follow in chapter two.

Literature Review

1.8 Introduction

The literature pertaining to post-operative ACL rehabilitation will be discussed in the following sections:

- Search strategy
- Incidence of ACL injury
- Anatomy and biomechanics of the ACL
- Risk factors and mechanism for injury of the ACL
- Management of ACL injuries
    - Medical management
    - Physiotherapy management
        - Accelerated vs non-accelerated ACL rehabilitation protocol
        - Commencement of rehabilitation Preoperative vs post-operative
        - WB protocol
        - Protective bracing
        - Mobilisation of knee joint
        - Return to function
        - Return to sport
        - Treatment management strategies
        - Treatment modalities used in rehabilitation
        - Exercise prescription for post-operative ACL rehabilitation
        - Current outcome measures used for assessment of post-operative ACL rehabilitation

1.9 Search strategy

Literature was found using PubMed, Clinical Key, Pedro, Medline, Ebscohost and Google Scholar via the university of Witwatersrand libguides. The key search words included ACL rehabilitation, ACL accelerated protocol, protective bracing, return to sport, epidemiology, physiotherapy modalities, and survey literature was sourced from 1996 to 2022. The search included articles from 1996 because this was the time that the non- accelerated protocols for ACL rehabilitation were started.

1.10 Incidence of ACL injuries

No South African statistics could be found regarding the epidemiology and incidence of ACL injury during the literature search conducted for this study.

International epidemiology was found in a retrospective study written by Singh et al (2018). In this article, the incidence of ACL injury in the general population was analysed using national databases and insurance claims. They found that the incidence per 100,00 population in these six countries was as follows: Norway (34), Denmark (32), Sweden (28), Germany (32), USA (29) and New Zealand (37). After looking at the general population they compared the incidence of injury in specific sports types in those different countries. The sports types that they looked at were soccer, skiing, and basketball. They found that there was a difference in incidence in the same sports types in those different countries. This suggests that the incidence is not only determined by genetics and environmental differences in the population but also due to different training methods for the same sport in the respective countries.

In a descriptive epidemiological study written in the USA by Joseph et al (2013), they compared the incidence of injury between the different sexes and types of sport in high school students. For this study, all high schools with one or more National athletic trainers-affiliated high school certified athletic trainers were invited to participate. The participating trainers reported the incidence of injuries from 2008 until 2012. During this time, they reported 617 ACL injuries. The incidence rate was found to be higher in competition compared to training, contact injury was more common than non-contact injury. In this study, they also found that girls had a higher rate of injury compared to boys. Concerning the type of sport, girls' soccer had the highest incidence followed by boys' football, boys' basketball and baseball. Similar findings were published in a more recent descriptive epidemiological study written in the USA by Gupta et al (2020). The data collection time was from 2007 until 2017. In this study, they also used the athletic trainers from 100 randomly selected schools and evaluated only the incidence of injury with soccer. They found that incidence was higher in competition compared to training, and in girls compared to boys. Overall there was a higher rate of injury with non-contact causes of injury.

The question is how many of the patients that sustain an ACL injury end up going for surgical intervention. In a Level 3 cohort study done in the USA by Collins et al (2013), they looked at the percentage of adult patients that underwent surgical intervention following an ACL injury compared to the total incidence of injury. They found that of the 2304 patients diagnosed with ACL injury between 2003 and 2007, 22,6% underwent reconstruction surgery.

1.11 Anatomy and biomechanics of the ACL

The knee joint is a synovial hinge joint of the lower limb. Anatomically the ACL is made up of two parts: a larger posterolateral bundle and a smaller anteromedial bundle (Musahl *et al.*, 2012) as seen in fig 2.1.

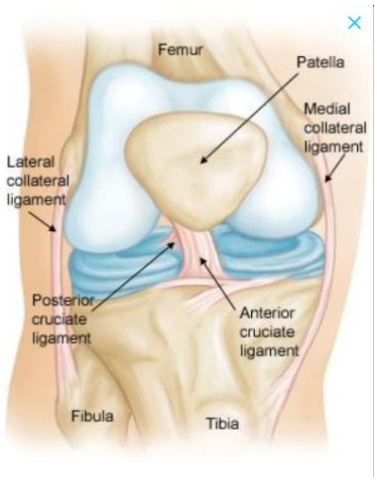

Figure 0.1 Anatomy of the knee Joint (orthoinfo.aaos.org/en/diseases--conditions/common-knee-injuries/)

The function of the ACL is to protect the knee from rotational loads and anterior tibial translation though its ROM and in WB (Sakane *et al.*, 1999). During the active NWB ROM of the knee, the larger posterior bundle relaxes with knee flexion. This allows the tibia to rotate internally when the quadricep muscles contract eccentrically (Naik, Das and Kamat, 2019). When the knee joint moves through the ROM into extension in closed kinematic movements, the larger posterior bundle locks the knee in full extension and protects against hyperextension by preventing posterior tibial movement (Musahl *et al.*, 2012; Marieswaran *et al.*, 2018). In contrast, the anteromedial bundle of the ACL protects the tibia from anterior movement in the end range of knee flexion

(Sakane *et al.*, 1999). During the gait cycle, the combined function of the anterior and posterior bundle of the ACL helps with the stability during WB in extension and allows for movement during flexion (Musahl *et al.*, 2012). The biomechanics of the knee can be seen in fig 2.2.

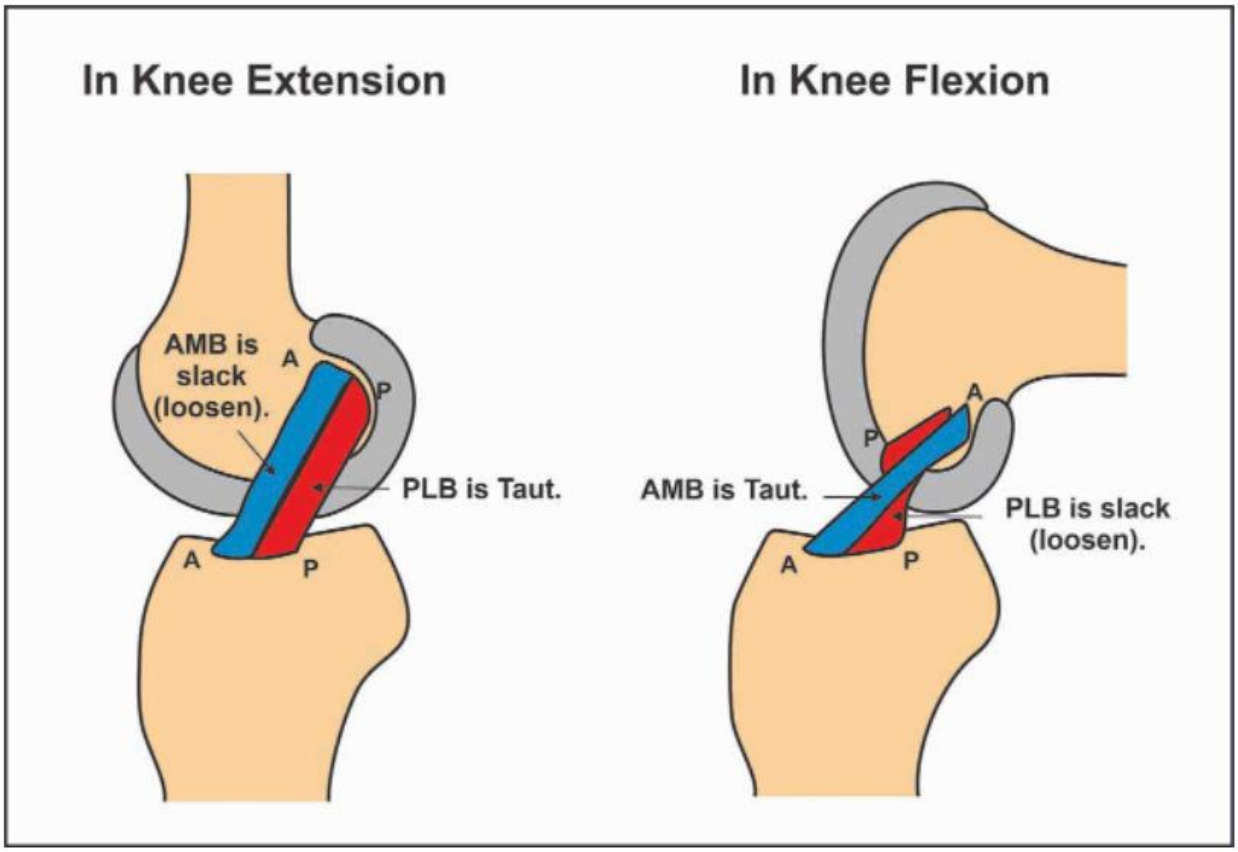

Figure 0.2: Biomechanics of the knee joint (physio-study.com/posterior-cruciate-ligament-anatomy-and-biomechanics/#more-2423.)

The knee moves through flexion and extension range with the antagonistic contraction of the quadricep muscles and the hamstring muscles. The flexion and extension of the joint are accompanied by rotation of the tibia and the anterior and posterior movement between the tibia and the femur. This movement between the articulating surfaces needs to be controlled to counteract the ground reaction forces and the shear forces around the joint for joint stability and prevention of dislocation. This is accomplished by the ACL (Marieswaran *et al.*, 2018).

The ACL not only contributes to the movement and stability of the knee joint but also plays an important part in the proprioceptive input to the knee joint due to the multiple nerve endings found within the fibers of the ligament (Markatos *et al.*, 2013).

1.12 Risk factors and mechanism for injury of ACL

In a systematic review by Acevedo et al (2014), they listed the modifiable and non-modifiable intrinsic factors as well as the modifiable extrinsic factors that predispose individuals to ACL injuries. The modifiable intrinsic factors include body mass index, neuromuscular and biomechanical factors, fatigue, and hormonal differences. The intrinsic non-modifiable factors include femoral notch size, female gender, posterior tibial slope, previous injury, and genetics. They described the extrinsic modifiable factors as the type of sport, level of participation in sport, shoes, weather, and surfaces that they play sport on. Similar intrinsic and extrinsic factors were also mentioned in a systematic review by Pfeifer et al (2018). This systematic review aimed to evaluate the risk factors that lead to non-contact ACL injuries. They found that the extrinsic factors included: weather, playing surfaces, sports level, sports type, and sports participation. The intrinsic factors were divided into anatomical, psychological, neuromuscular, biomechanical and genetic categories.

To injure the ACL a specific event with a specific mechanism of injury must occur, even if some or all intrinsic and extrinsic factors are present (Hewett *et al.*, 2016). While the ACL can be ruptured by contact injuries, it is more often ruptured due to non-contact injuries, usually when there is hyperextension of the knee or a sudden change in direction while moving (Mclean, 2007; Boden *et al.*, 2010; Singh, 2018). Most non-contact injuries occur during landing or deceleration (Boden and Sheehan, 2022).

The manuscript published by Boden and Sheehan (2022), summarized the findings from 100 reports that were published by their research team on how to prevent ACL injuries. These articles were published between 1996 and 2016 in orthopaedic, sports medicine and biomechanical-related peer-reviewed journals. In this manuscript, they looked at risk factors and the mechanism of injury of ACL injuries. They described the biomechanics mechanism of injury during non-contact injury as a “valgus collapse mechanism with potential multi-planar loads of tibial abduction combined with anterior tibial translation or external or internal tibial rotation”. This collapse causes increased multiplanar compression forces and leads to abduction, anterior translation or rotation of the tibia. This is similar to the overview of the non-contact ACL injury portion of the OREF 2022 research award, and the manuscript was published by Boden and

Sheehan. The authors of the study found that increased eccentric quadriceps contraction and abduction of the tibia increases the axial compressive forces around the knee which increases the risk for ACL injury (Boden and Sheehan, 2022).

In conclusion, ACL injuries occur more often due to non-contact injuries and the mechanism of injury usually includes hyperextension of the knee or a sudden change in moving direction, irrespective of the intrinsic and extrinsic factors that may be present.

1.13 Management of ACL injuries

1.13.1 Medical management of ACL injuries

The motivation for ACL repair using surgical intervention mentioned in the literature includes recovering stability of the knee joint to prevent injury to other ligaments and the meniscus and cartilage of the knee and helping the patients to return to the preinjury level of sport (Ardern *et al.*, 2011).

Sherman et al (2021) described the results of a survey that was sent to an international ACL study group. This ACL study group was established in 1967 with the goal of evaluation and improving the outcomes of ACL injury intervention. This study has a level V level of evidence and is categorised as an expert opinion. This survey was distributed in 2020 among the members of the ACL study group before their meeting in January 2020. A total of 140 members completed the survey. The survey aimed to establish the current global trends in ACL repair. In this survey, 92% of the participants believed that surgery is the only option for treatment for ACL injuries. Ninety per cent of surgeons performed a single bundle ACL reconstruction and only seven per cent performed double-bundle ACL reconstruction. The choices of primary graft included hamstring tendon graft autograft, bone-tendon-bone autograft, and quadriceps tendon autograft. The most used primary graft choice was hamstring tendon autograft followed by bone-tendon-bone graft and then quadricep tendon autograft. There was a variety of responses to where the tunnel should be. This was echoed by the evidence-based guidelines written by Shea et al (2015) which indicated that surgical intervention is the current standard clinical treatment of ACL injuries. In this systematic review, they

evaluated the current clinical research and wrote guidelines with recommendations about assessment, surgical intervention, and rehabilitation of ACL injuries. Regarding the surgical intervention, they strongly recommended the use of intra-articular single or double-bundle reconstruction. Regarding autograft source, they strongly recommend the use of bone-patellar-tendon-bone or hamstring tendon grafts. With regards to the femoral tunnel techniques, there was moderate evidence for the use of a tibial independent approach or transtibial approach for the femoral tunnel.

1.13.2 Complications and disability

The possible complications following ACL reconstruction include deep vein thrombosis, surgical site infection, graft rupture, complex regional pain syndrome, stiffness of the knee, weakness of the quadricep muscle, patellofemoral problems and loss of knee extension (Shelbourne, Klootwyk and DeCarlo, 1992; Acevedo *et al.*, 2014; Bordes *et al.*, 2017; Samuelsen *et al.*, 2017). The potential long-term (secondary) complications associated with ACL injury incudes chronic knee instability, meniscus tear, cartilage injury and osteoarthritis (Acevedo *et al.*, 2014). Osteoarthritic changes inside the knee are irreversible and this degeneration could lead to severe disability earlier in life (Lewis *et al.*, 2018).

1.13.3 Physiotherapy management

“Post-operative rehabilitation is a major factor contributing to the success of ACL repair” (Janssen *et al.*, 2018). The initial aim of rehabilitation is to increase ROM, muscle strength and balance but it should protect the surgical graft (Markatos *et al.*, 2013). The overall aim of rehabilitation is to return the patient to their highest functional level safely, and as soon as possible, and to prevent complications after ACL reconstruction (Greenberg *et al.*, 2018).

There have been some suggestions about specific protocols for post-operative ACL rehabilitation. These include early mobilisation, early WB, no protective bracing and an accelerated protocol (Eitzen *et al.*, 2010; Wright *et al.*, 2015; Van Melick *et al.*, 2016; Gupta *et al.*, 2017; Wilk and Arrigo, 2017; Filbay and Grindem, 2019).

But the question is, what current perspective and protocols are physiotherapists globally using for post-operative ACL rehabilitation? This answer can be found in recent surveys done across the physiotherapy population globally. One of these surveys was completed in 2022 in New Zealand where they evaluated the perspective regarding rehabilitation and return to sport after ACL reconstruction. The study was a cross-sectional online survey with 318 completed responses with an estimated response rate of 29.3%. This survey aimed to establish the practice around preoperative and post-operative rehabilitation and when the patient should return to sport. They found that 57% of the participants started treatment one-week post-surgery while 28.4% waited until seven to 14 days post-operatively. During the first six weeks, the follow-up was one to two times a week for 91% of the participants. With regards to return to sport, 11% reported that their patients returned to sport between six to nine months post operatively, but 63,2% only returned from nine to 12 months. The limitation of this study was noted that more than 90% of the participants saw less than 40 post-operative ACL injury patients per year (Fausett, Reid and Larmer, 2022).

Another survey was done in Brazil by Auino et al (2021). This cross-sectional study used a self-developed questionnaire to establish the criteria for return to sport post ACL rehabilitation. This questionnaire was sent to physiotherapists via social media using Facebook, Instagram, WhatsApp, and email. A total of 481 responses were received, 26 were excluded due to exclusion criteria, and nine refused to participate. The total number of participants was 439. The purpose of the study was to establish when patients return to sport post ACL rehabilitation, who determines if the patient can return to sport and what outcome measures the physiotherapist used to determine if the patient can return to sport. Most of the participants reported that they used physical assessment to determine return to sport. The use of self-reported functional status and psychological readiness was only included for 20% of participants. From the survey, they concluded that there was a discrepancy between the criteria for return to sport compared to current literature and what factors determine the return to sport in clinical practice.

A survey done by a physiotherapist in Greece in 2021 aimed to evaluate the assessment and treatment principles that physiotherapists use, as well as the criteria they use to evaluate the return to sport after ACL rehabilitation. This survey yielded

639 responses of which 93 were excluded due to incomplete questionnaires. The survey comprised of seven sections: demographic and professional characteristics, time, the point when rehabilitation post-operative ACL rehabilitation starts, clinical evaluation measures, time, criteria when open kinetic chain (OKC) exercises are started, criteria for progression to running, criteria for return to sport, and recommendations on an injury prevention programme. In the survey, the first objective was to compare the timing, importance, and frequency of rehabilitation to current literature. They found that in Greece 83,3% of participants started rehabilitation in the first week post-operatively compared to the literature. The outcome measures mostly used included ROM measured with a goniometer, and extrapolated strength measurements from a single hop test. With regards to when OKC exercises were started, the options included time-based (time since surgery), criteria-based (ROM, graft type and signs and symptoms) or both. They found that 63.3% of participants started OKC exercises when both time and specific criteria were met. Functional strength and ROM were found to be the determining factors for patients to start running. When determining the time of return to sport, 58.7% of the participants suggested that return to sport takes between six to nine months. Regarding criteria for return to sport, 73.6% of the participants indicated that they determined the functional capacity to return to sport by a battery of hop tests. From this survey, they concluded that the principles used in clinical practice in rehabilitation depended on the physiotherapists' experience and how many post-operative ACL patients they see in the practice. They suggested that more research is required to establish the barriers that prevent physiotherapists from adapting their treatment to more evidence-based according to current literature (Korakakis *et al.*, 2021).

Dringenen et al. (2021) evaluated the rehabilitation strategies of physiotherapists in Belgium using an online questionnaire that they distributed via the database of the local physiotherapy organisation. The questionnaire included questions regarding protocols for rehabilitation: preoperative rehabilitation, the criteria-based progression of post-operative rehabilitation, and what guides the return to sport decision. The physiotherapist was then asked to evaluate their self-related confidence and competence in the treatment of post-operative ACL patients. A total of 283 physiotherapists participated in this study but they were unable to establish a correct sample size due to the distribution method of the survey. They concluded that there was a great variety of different rehabilitation protocols and criteria for return to sport.

Even with the discrepancy found between the current literature and clinical practice, the physiotherapists rated their confidence and competency regarding rehabilitation high.

From these surveys, we can conclude that there is a great variety of protocols and guidelines for post-operative ACL rehabilitation. This is also echoed in the literature where it was found that there is no consensus regarding the optimal rehabilitation programme and the time to return to sports after ACL reconstruction (Eitzen *et al.*, 2010; Yabroudi and Irrgang, 2013; Makhni *et al.*, 2016; Cristiani *et al.*, 2021). This variety in protocols, modalities and time frames could confuse patients and therapists (Makhni *et al.*, 2016). Some of the different protocols for post-operative rehabilitation are shown in the following figure and tables. These include figure 2.3 Five-week exercise programme by Eitzen et al (2010), table 2.1 The rehabilitation protocol of Yabroudi and Irrgang (2013), table 2.2 Rehabilitation protocol by Makhni et al (2016), and table 2.3 The standard and accelerated rehabilitation protocol by Cristiani et al (2021). Eitzen et al (2010) described a very specific five-week exercise programme that explained in detail what exercises should be done and when these exercises should be initiated. In comparison, Yabroudi and Irrngang (2013) and Makhni et al (2016) developed comprehensive protocols for post-operative ACL rehabilitation. These protocols are similar with regard to modalities and exercises but differ in the time frame of when these modalities and exercises should be initiated. Cristiani et al (2021) compared the standard protocol to the accelerated protocol they developed. In this comparison the treatment modalities and exercises are similar but again it can be seen the timeframe for initiation of these modalities and exercises differ.

PERTURBATION TRAINING PROTOCO L

Sessions 1–4. Early Phase

Progression by adding perturbations in all directions and minimizing of verbal cues

Session	Activity: Rocker Board	Roller Board/Platform	Roller Board
1	• Bilateral stance • 2 sets, anterior/posterior • 2 sets, medial/lateral	• 2 sets with injured limb on roller board, anterior/posterior • 2 sets with uninvolved limb on roller board, anterior/posterior	• Bilateral stance • 2 sets anterior/posterior
2	• Unilateral stance • 2 sets anterior/posterior direction • 2 sets medial/lateral direction	• 2 sets with injured limb on roller board, anterior/posterior plus medial/lateral • 2 sets with uninvolved limb on roller board, anterior/posterior plus medial/lateral	• Unilateral stance • 2 sets anterior/posterior
3	• Unilateral stance • 2 sets medial/lateral direction • 2 sets diagonal direction	• 2 sets with injured limb on roller board, anterior/posterior plus medial/lateral plus rotation • 2 sets with uninvolved limb on roller board, anterior/posterior plus medial/lateral plus rotation	• Unilateral stance • 2 sets anterior/posterior plus medial/lateral
4	• Unilateral stance • 2 sets medial/lateral direction • 2 sets diagonal direction	• 2 sets with injured limb on roller board, anterior/posterior plus medial/lateral plus rotation • 2 sets with uninvolved limb on roller board, anterior/posterior plus medial/lateral plus rotation	• Unilateral stance • 2 sets anterior/posterior plus medial/lateral plus rotation

Sessions 5–7: Middle Phase

Progression by adding light sport-specific activity during perturbations

Session	Activity: Rocker Board	Roller Board/Platform	Roller Board
5	• Unilateral stance • 2 sets anterior/posterior direction • 2 sets medial/lateral direction • 2 sets diagonal direction • Ball against wall	• 2 sets with injured limb on roller board, anterior/posterior plus medial/lateral plus rotation • 2 sets with uninvolved limb on roller board, anterior/posterior plus medial/lateral plus rotation • Ball against wall	• Unilateral stance • 2 sets anterior/posterior plus medial/lateral plus rotation • Ball against wall
6	• Unilateral stance • 2 sets anterior/posterior direction • 2 sets medial/lateral direction • 2 sets diagonal direction	• 2 sets with injured limb on roller board, anterior/posterior plus medial/lateral • 2 sets with uninvolved limb on roller board, anterior/posterior plus medial/lateral	• Unilateral stance • 2 sets anterior/posterior plus medial/lateral plus rotation

PERTURBATION TRAINING PROTOCOL

Sessions 1–4. Early Phase

Progression by adding perturbations in all directions and minimizing of verbal cues

Session	Activity		
	Rger Board	Roller Board/Platform	Roller Board
	• Ball against wall/floor	• Ball against wall/floor	• Ball against wall/floor
7	• Unilateral stance • 2 sets medial/lateral direction • 2 sets diagonal direction • Ball thrown by other	• 2 sets with injured limb on roller board, anterior/posterior plus medial/lateral • 2 sets with uninvolved limb on roller board, anterior/posterior plus medial/lateral • Ball thrown by other	• Unilateral stance • 2 sets anterior/posterior plus medial/lateral plus rotation • Ball thrown by other

Sessions 8–10: Late Phase

Progression by adding sport-specific stances combined with sport-specific activity

Session	Activity		
	Rocker Board	Roller Board/Platform	Roller Board
8	• Unilateral stance • 2 sets anterior/posterior direction • 2 sets medial/lateral direction • 2 sets diagonal direction • Ball against wall/floor, thrown by other • Other individually adjusted relevant sport-specific activities	• 2 sets with injured limb on roller board, anterior/posterior plus medial/lateral plus rotation • 2 sets with uninvolved limb on roller board, anterior/posterior plus medial/lateral plus rotation • Ball against wall/floor, thrown by other • Other individually adjusted relevant sport-specific activities	• Unilateral stance • 2 sets anterior/posterior plus medial/lateral plus rotation • Ball against wall/floor, thrown by other • Other individually adjusted relevant sport-specific activities
9	• Unilateral stance • 2 sets medial/lateral direction • 2 sets diagonal direction • Ball against wall/floor, thrown by other • Other individually adjusted relevant sport-specific activities	• 2 sets with injured limb on roller board, anterior/posterior plus medial/lateral plus rotation • 2 sets with uninvolved limb on roller board, anterior/posterior plus medial/lateral plus rotation • Ball against wall/floor, thrown by other • Other individually adjusted relevant sport-specific activities	• Unilateral stance • 2 sets anterior/posterior plus medial/lateral plus rotation • Ball against wall/floor, thrown by other • Other individually adjusted relevant sport-specific activities
10	• Unilateral stance • 2 sets medial/lateral direction • 2 sets diagonal direction • Ball against wall/floor, thrown by other • Other individually adjusted relevant sport-specific activities2	• 2 sets with injured limb on roller board, anterior/posterior plus medial/lateral plus rotation • 2 sets with uninvolved limb on roller board, anterior/posterior plus medial/lateral plus rotation • Ball against wall/floor, thrown by other • Other individually adjusted relevant sport-specific activities	• Unilateral stance • 2 sets anterior/posterior plus medial/lateral plus rotation • Ball against wall/floor, thrown by other • Other individually adjusted relevant sport-specific activities

Figure 0.3: Five-week exercise programme by Eitzen et al (2010)

Table 2
Summary of the critical milestones for progression of rehabilitation after anatomic ACL reconstruction

Early Postoperative	Strengthening and Neuromuscular Control	Return to Activity and Sports
Patients should be able to walk normally without crutches or gait deviation	Patients should have no difficulty with daily activities	Patients should achieve a quadriceps index of 85% or greater
Have full passive knee extension symmetric to the noninvolved knee	Should tolerate all strength and flexibility exercises without evidence of joint pain or inflammation	Have satisfied all the previous criteria (appropriate ROM, strength, proprioception, and endurance) for functional progression
Have at least 100°–120° of knee flexion	Should be able to jog 3.2 km (2 miles) (if possible previous to injury) and tolerate submaximal multidirectional functional activities	Able to tolerate full-effort sprinting, cutting, pivoting, jumping, and hopping drills
Have no evidence of an extensor lag		
Have minimal effusion or other signs of active inflammation		

Figure 0.4: Rehabilitation Protocol of Yabroudi and Irrgang (2013)

Table 1. Rehabilitation Protocol Components

Prehabilitation	Range of motion, quadriceps strengthening
Postoperative adjunct therapy	Continuous passive motion, brace use, neuromuscular electric stimulation
Early motion and weight bearing	Flexion/extension goals, weight-bearing parameters
Strengthening	Straight-leg raise, resisted straight-leg raise, quadriceps sets/isometrics, ankle pumps, minisquats, squats, hamstring curls, resisted hamstring curls, leg press, step-up/down, wall sits, single-leg squats, resisted knee extension, lunges
Proprioception	Weight shifting, 1-leg balance, balance board, ball toss, perturbation, balance beam, Theraband control, mini-trampoline balance
Functional testing	Single-hop test, 3-hop test, isokinetic quadriceps strength, isokinetic hamstring strength, quadriceps/hamstring strength ratio, or nonspecific functional test
Activity/sport	Stationary bike, backwards walking, normal gait, elliptical, stair climber, aqua jogging, underwater treadmill, swimming, backwards running, straight-line running/jogging, jumping/plyometrics, cutting/pivoting, agility (carioca, side shuffle), sport-specific drills, return to practice/sport

Figure 0.5: Rehabilitation protocol by Makhni et al (2016)

Standard	Accelerated
Perform isokinetic strength test and single-leg-hop test before ACLR	
Postoperatively	
	1-3 weeks Perform passive and active full ROM and full weight-bearing, closed kinetic chain exercises with limited (0-50 degrees) ROM, straight-leg raises (extension, flexion, abduction, adduction), heel rises, balance/proprioceptive training, stationary bicycle when 110 degrees of knee flexion achieved
1-6 weeks Perform passive and active full ROM and full weight-bearing, closed kinetic chain exercises with limited (0-50 degrees) ROM, straight-leg raises (extension, flexion, abduction, adduction), balance/proprioceptive training, stationary bicycle when 110 degrees of knee flexion achieved	
	4-6 weeks Closed and open kinetic chain exercises with ROM between 0 and 90 degrees, training of the upper body and trunk
	7-8 weeks Increase closed and open kinetic chain exercises, increase balance/proprioceptive training, frontal and lateral step-ups, lunges with weight, slide board, stair-master, cycling
7-12 weeks Increase closed kinetic chain exercises, increase balance/proprioceptive training, frontal and lateral step-ups, lunges with weight, slide board, stair-master, heel rises	
	9-12 weeks Start running and plyometric exercises, sub-maximum closed and open kinetic chain exercises
3-4 months Increase closed kinetic chain exercises and start open kinetic chain exercises with full ROM, increase balance/proprioceptive training, start running and plyometric exercises, cycling, start perturbation training and sports-specific drills	**3-4 months** Increase running programme and plyometric exercises, maximum closed and open kinetic chain exercises, cuttings and perturbation training, sports-specific drills
5-6 months Increase running and plyometric programme, cuttings, perturbation training and sports-specific drills	

Figure 0.6: Standard and accelerated rehabilitation protocol by Cristiani et al (2021)

1.13.3.1 Accelerated vs non-accelerated ACL rehabilitation protocol

To understand when the traditional or non-accelerated and accelerated protocols originated, the literature search extended up to 1992. In an article written by De Carlo et al (1992) they described the traditional or non-accelerated ACL rehabilitation protocol that was originally published in 1981 by Paulos et al. This protocol consisted of immobilisation of the knee joint in a cast at 30 degrees of knee flexion for two weeks, whereafter the cast was replaced by a hinged brace. This brace was weaned at four months post operatively. The patient was NWB for eight to 10 weeks and could start partial weight-bearing (PWB) thereafter. After 12-14 weeks the patient started full weight-bearing (FWB), and some isokinetic exercises was initiated at that time too. From nine to 12 months the patient were allowed to return to normal function if they had full ROM and good strength to do so. The problems associated with this protocol were decreased ROM which required manipulation, and the formation of excess scar tissue that had to be surgically removed. During the time that this was the gold standard of rehabilitation, it was found that the non-compliant patients that did not follow the WB protocol and exercise prescription as per the protocol, recovered better and had fewer complications. This was the driver of developing more accelerated protocols. (De Carlo *et al.*, 1992).

A systematic review by Andrade et al (2020*)* did not find a conclusive definition of accelerated rehabilitation but generally, it was described as a shorter rehabilitation period with early WB, joint mobilisation, and early progression of OKC and closed kinetic chain (CKC) exercises. In a retrospective study by De Carlo et al (1992) the accelerated protocol included early WB, early knee ROM mobilisation, emphasis on terminal extension of the knee joint and prescription of a CKC exercise programme to increase knee flexion ROM. In this study they compared patients that were rehabilitated via the non-accelerated protocol and the accelerated protocol. The data for three months, six months and 12 months were compared and it was found that the accelerated protocol had better outcomes than the non-accelerated protocol when ROM, strength and stability were compared (De Carlo *et al.*, 1992). Similar results were published by Shelbourne et al (1992) with a new focus on patient education in regards to what exercises and activities of daily living they can do instead of what they are not allowed to do (Shelbourne, Klootwyk and DeCarlo, 1992).

The concern with following an accelerated programme is that the reconstructed ligament will become laxer. An additional risk were found where the graft was not healing properly (Beynnon *et al.*, 2011). The prospective double-blinded randomised control trail done by Beynnon et al (2011) found that there was no significant difference in laxity and clinical assessment between the two protocols. In this study, the accelerated protocol was defined as weaning crutches at day eight post-operatively and progressing to FWB, an earlier start of isometric and concentric quadricep muscle contraction. The same exercises were only initiated in the non-accelerated group when the estimated time for graft healing (that they did not specify) was met and WB without crutches only after day 22. In this study, they found that the amount of laxity after accelerated rehabilitation and non-accelerated rehabilitation protocols were the same. This indicating that the accelerated protocol does not cause more laxity than the non-accelerated rehabilitation protocol (Beynnon *et al.*, 2011). Similar results were described in a prospective randomised control tail study done by Gupta et al (2017) but they found that their clinical outcomes were better than with the non-accelerated protocol after semitendinosus graft.

In a systematic review by Janssen et al (2018), they wanted to evaluate the outcomes of different rehabilitation protocols, surgical interventions, and patient characteristics on outcomes after a hamstring tendon graft. They defined accelerated rehabilitation as early unrestricted ROM, passive knee extension, immediate WB without a ROM brace and OCK exercise within limited ROM (45 to 90 degrees) that started at four weeks post-operatively. The progressive concentric and eccentric exercises were only started after 12 weeks. They wanted to compare the results in other studies that evaluated outcomes of patella tendon graft compared to hamstring graft. They found no significant difference between outcomes of the patella tendon graft and hamstring tendon grafts.

In a similar systematic review by Nelson et al (2021) concluded that a six-week accelerated protocol showed significant improvement in pain scores and knee ROM at eight weeks post-operatively. The accelerated protocol also had the added benefit on the psychosocial aspect of recovery, and it showed that these patients have a higher quality of life in the short term but more research in this regard is required.

In contrast to the study done by Nelson et al (2021), a randomised controlled trial done by Cristiani et al (2021) found no difference in outcomes of muscle strength between the standard and accelerated protocols post ACL rehabilitation. The standard treatment protocol must not be confused with the non-accelerated protocol described by Paulos in 1981. The standard protocol used by Cristiani et al (2021) was described as passive and active full ROM, FWB, CKC exercises with limited (0-50) ROM (as seen in fig 2.6), straight leg raise, balance/proprioception training and stationary bicycle when they reach 110 degrees knee flexion within the first six weeks post-operatively. From seven to 12 weeks, they progressed the CKC exercises, increased balance, and proprioception training. From three to four months, they started with OCK exercises, plyometrics and sport-specific drills. The main difference between the standard protocol and accelerated protocol was the time frame of the initiation of OCK exercises. Regarding the accelerated protocol, they initiated open and CKC exercises up to 90 degrees of knee flexion from week three and then progressed this exercise until week seven. From seven to eight weeks, they increased the OCK and CKC exercise programmes. They started with running and plyometrics from week nine to 12.

As per literature, the accelerated rehabilitation includes the following: Immediate WB, early unrestricted progressive ROM and gaining knee extension. While a non-accelerated programme includes immobilisation for the first two weeks, with progressive ROM only after the stability of the ACL graft is determined, NWB mobilisation with progression to FWB six weeks post-operatively, Table 2.1 outlines the differences between the Accelerated and non-accelerated protocols found in the literature.

Table 0.1: Accelerated vs non-accelerated protocol

Accelerated Protocol	Non-accelerated protocol
• Early unrestricted progressive ROM • Immediate progressive WB • Immediate progressive knee extension ROM	• Knee immobilisation for the first two weeks, with progressive ROM only after the stability of the ACL graft is determined. • NWB mobilisation with progression to FWB after six weeks post-operatively.

1.13.3.2 When should rehabilitation start preoperatively or post-operatively?

According to Wilk and Arrigo (2016), the purpose of preoperative rehabilitation include: preparing the patient physically and psychologically for the surgery, decreasing the risk of post-operative complications and improving the changes of successfully returning to function and sport, and decreasing the risk of re-injury. They suggest that preoperative rehabilitation should aim to reduce swelling, inflammation, and pain, and restore ROM and quadricep control, followed by the restoration of neuromuscular control of the knee. Swelling, inflammation and pain can be reduced by physiotherapy with the use of cryotherapy, passive ROM, and electrical stimulation. With regards to the restoration of ROM, the first aim is to gain full knee extension and then progress to regaining flexion. They suggest that 0-120 degrees of knee range could be achieved by the 10th day of preoperative rehabilitation. To improve the quadricep muscle function post-operatively, the use of isometric exercises and electrical stimulation was suggested preoperatively. Furthermore, proprioceptive training should be initiated when there is a reduction in swelling and pain, and restoration of ROM and quadricep muscle control has been established. This is achieved by weight-shifting exercises and mini squats. A total of 21 days is required for pre-operative rehabilitation to attain these goals.

In the manuscript written by Filbay and Gindem (2019), they aimed to provide practical recommendations for management ACL rehabilitation. They suggested that the goal of preoperative rehabilitation is to decrease swelling, restore ROM, and improve quadricep strength. Furthermore, preoperative rehabilitation benefited patients up to two years post-operatively. However, if the patients had decreased ROM and increased swelling preoperatively it increased the risk of poor outcomes after surgery (Filbay and Grindem, 2019). This was echoed in a systematic review by Giesche et al (2020) who evaluated the research regarding preoperative and post-operative rehabilitation. The study aimed to evaluate the potential benefit of preoperative rehabilitation of pre- and post- operative objectives, self-reported function and return to sport-specific outcomes. In their results, they found that preoperative rehabilitation improved the patient's neuromuscular function and their chances of a return to sport. However, in this study, only six studies were referenced, and limited databases were sourched for research. More high-quality randomised control trails are required in this field.

In contrast, the systematic review by Carter et al (2020) found that there is low-quality research to support the suggestion that there could be an improvement in muscle strength, function and return to sport in patients who received preoperative rehabilitation in comparison to patients who did not. In this review, they found that there was a large variety in preoperative protocols, number of sessions and time frames for preoperative rehabilitation. There was no significant difference in the quadricep and hamstring muscle strength of patients that had preoperative rehabilitation. They did however find that function assessed via the single leg hop distance was significantly better at 12 weeks in the patients that had preoperative rehabilitation. Overall, the patients who had preoperative rehabilitation did not return to sport earlier in comparison to patients that started rehabilitation post-operatively, only. They concluded that the evidence for preoperative rehabilitation is still limited and that there was a gap in the research regarding the psychological aspect and the barriers that play part in the recovery of patient post ACL injury.

According to the literature, there is a large variety in protocols, number of sessions and time frames for preoperative rehabilitation. It is suggested that preoperative rehabilitation should be done to decrease swelling, restore ROM, and improve muscle strength to prevent post-operative complications like loss of ROM, patellofemoral pain, and muscle weakness.

1.13.3.3 WB protocol

Early WB is encouraged in the literature (Andrade *et al.*, 2020). It is recommended that the patients should progress to FWB immediately post-operatively as tolerated. The effect of early WB include improvement in ROM outcomes, decreased quadriceps muscle wasting and increased quadriceps strength (De Carlo and Sell, 1997; Wright *et al.*, 2008b; Adams *et al.*, 2012; Naik, Das and Kamat, 2019; Andrade *et al.*, 2020; Jenkins *et al.*, 2022).

According to Janssen et al's (2018) systematic review they looked specifically at the hamstring autograph and accelerated protocol. It was found that walking with a normal gait pattern and WB without crutches within the first 10 days post-operatively decreases the amount of quadricep muscle strength that is lost and thus prevents the development of patellofemoral pain. The early WB (as pain allows) and normal gait

pattern do not affect the stability of the knee. This was also supported by the systematic review by Andrade et al (2020) that suggests that early WB should be encouraged but must progress as the patient can tolerate.

The systematic review by Fan et al (2022) concluded that early WB leads to increased laxity and an increase in tunnel diameter of the graft. They recommended delayed WB up to eight weeks and careful selection of rehabilitation protocol for the best result of knee stability. In this study, they included 911 articles that were eligible but only nine studies that met the criteria were used. The inclusion criteria consisted of comparison of delayed or accelerated rehabilitation protocols in patients after ACLR; arthroscopic surgical intervention, mean age of participants 18 years and older, randomized, controlled, retrospective or prospective trails. Two of the nine articles showed significant bone tunnel enlargement with early WB. In seven of the articles the knee laxity was measured with arthrometer. From the seven studies only two reported a greater degree of laxity. In contrast, it was found in the systematic review by Jenkins et al (2022) that early WB is important for ROM and function of the knee post-1operatively. The selection of early activities like WB and exercise to achieve these goals should be done safely to prevent complications like laxity and bone tunnel enlargement.

In conclusion, it is suggested that patients progress to FWB as soon as it can be tolerated to prevent complications like laxity and bone tunnel enlargement.

1.13.3.4 Protective bracing

Protective bracing aims to protect the healing tissue, decrease swelling, prevent injury to the graft and give the patient more confidence whiles it aids early joint movement (Wright *et al.*, 2008b; Andrade *et al.*, 2020). The protective braces are effective in preventing anterior translation of the femur on the tibia but the ability of the brace to protect from reinjury has not been validated in the literature. However, it is suggested by the literature that post-operative bracing should not be used for ACL ligament rehabilitation (Kurtz *et al.*, 2011; Wright *et al.*, 2015; Bordes *et al.*, 2017; Lowe *et al.*, 2017; Naik, Das and Kamat, 2019; Andrade *et al.*, 2020; Nelson *et al.*, 2021)

The retrospective study by Bordes et al (2017) evaluated the effect of rigid bracing, articulated brace, and no brace in early post-operative ACL rehabilitation. The repair grafts used in the study was hamstring and bone-patella- bone grafts. The study population included 969 patients of which 74% used the rigid brace, 19% the articulated brace and seven per cent had no brace. In this study, there was no significant difference found between the three groups regarding pain, ROM, muscle atrophy and walking quality. They found that there was an initial increase in ROM in the patients that had no brace but later in the rehabilitation process the ROM gained was equal. The limitations of this study was that they used a observational retrospective study instead of a prospective randomised study, and short follow up times with the patients. They concluded that the brace could increase the occurrence of post-operative complications like muscle atrophy and reduce flexion ROM initially when using a rigid brace, and the brace should only be used if the patient has a quadricep activation deficit that stops the knee from moving into terminal locking or if the surgical graft is fragile. Similar findings were published in a retrospective cohort study by Naik et al (2019) where they found that rehabilitation without protective bracing can indirectly protect against re-injury by preventing muscle atrophy with the early strengthening of the quadriceps muscle. The study limitation was that they had a small sample size (32 consecutive patients) but they had no re-ruptures of ACL during this study (Naik, Das and Kamat, 2019). In the systematic review written by Andrade et al (2020) they found that post-operative functional bracing was not supported by scientific evidence and the brace should only be considered when it is a more complex injury and other ligaments are involved.

1.13.3.5 Mobilisation of knee joint

The concept of immediate knee joint mobilisation has been the gold standard of treatment for at least the last two decades (Andrade *et al.*, 2020). The reason for immediate mobilisation is to prevent loss of knee extension. According to the systematic review written by Andrade et al (2020) immediate mobilisation, neuromuscular and strength training are important to prevent extension loss of the knee. The systematic review by Wright et al (2015), found that immediate gaining of flexion and extension ROM is a fundamental principle in post-operative ACL rehabilitation. Therefore, it is started by the physiotherapists as soon as rehabilitation

commences. However, the impact of immediate knee mobilisation was not studied in randomised control trails.

1.13.3.6 Return to function

A prospective longitudinal observational study by Obermeier et al (2018) found that early functional recovery is just as important as long-term return functional outcomes in post-operative ACL rehabilitation. The functional goals that this study looked at were decrease in pain to the point where they can discontinue using pain medication, when the patients stop using crutches, return to work or school and driving. In this study, they collected data from 182 patients pre-operatively, at weeks one, two, four, eight and 12 weeks post-operatively. They collected data about the functional milestones via a questionnaire. The results of the study found that the mean time for patients to stop using pain medication was day nine. They reported that crutches were weaned at day 15, the median day for return to work was day 11 and return to school seven days post-operatively. Most of the patients returned to driving by day 11. They concluded that rapid recovery and return to function happen mostly within the first month post-operatively, but this could be influenced by demographic characteristics. The systematic review by Andrade et al (2020) found that a minimum of three months is required for a patient to return to heavy activity and labour.

1.13.3.7 Return to sport

In the literature, there are varied opinions and protocols regarding the expected time of return to sport, as well as the criteria that determine if a patient is ready to return to sport. This can be seen in the comparison of surveys done by physiotherapists and surgeons that are part of the ACL study group as well as a systematic review that evaluates current trends in research (Sherman *et al.*, 2021; Fausett, Reid and Larmer, 2022).

Sherman et al (2021) discussed the survey that was completed by the ACL study group in 2020. The most common response regarding when patients return to sport was between six months and eight months (44% response rate) and 41% returned between nine months and 12 months. In this survey, they found that 71% of participants reported

that return to sport is determined by time criteria and functional assessment. In this article, they did not mention what functional assessment they used as criteria for return to sport.

If we compare this to the study by Fausett et al (2022) that evaluated surveys completed by physiotherapists in New Zealand in 2021 about the return to sport, 63% responded that their patients return to sport between nine and 12 months. Only 11% supported return to sport between six and nine months and 24% would wait 12 to 18 months. Regarding criteria for return to sport, they were much more specific: the most included considerations for return to sport were functional capacity, mechanics, strength, and psychological aspect. They concluded that 98.1% of physiotherapists look at functional capacity, 92.5% lower limb and trunk mechanics, 90% knee muscle strength and 89% psychological aspect of readiness to return to sport and 75% at the time after surgical intervention (Fausett, Reid and Larmer, 2022).

According to the Moon guidelines by Wright et at (2015) the patients usually return to sport between five to six months post operatively. In contrast, Baron et al (2020) found that the return to sport is usually six to nine months post-operatively. The systematic review by Andrade et al (2020) suggested that the criteria that determine return to sport should include clinical evaluation via Knee injury and osteoarthritis outcome score (KOOS), IKDC or Lysholm scores, functional evaluation via hop test and psychological assessment for readiness to return to sport.

The return to sport time frames in the literature varies and ranges from five to 12 months post-operatively. It is important not to base the decision on return to sport on specific time frames but rather on criteria that include clinical evaluation, functional evaluation, and psychological assessment.

1.13.3.8 Supervised physiotherapy vs Home-based physiotherapy

According to Czamara et al (2021), there is a significantly better recovery of strength in patients that has a six-month supervised post-operative ACL rehabilitation programme compared to patients that had fever sessions. The randomised control trial aimed to compare the outcomes of the patients who had more than 60 supervised sessions with patients who had less than 60 supervised sessions in 24 weeks post-

operatively. In this study, they had three groups. Group one had more than 60 sessions guided by the physiotherapist, whilst in the second group, the patients could decide on the number of times they wanted to follow up in 24 weeks. Group three was the control group that had 20 patients with no knee injuries. A total of 105 patients participated in the study and were then randomly allocated to a group. They concluded that an average of 75 supervised physiotherapy sessions was recommended to regain optimal strength similar to the patients' unaffected lower limb and the control group.

In the cohort study by Han et al (2015), 93 patients were instructed to attend 20 supervised physiotherapy sessions. The patients' outcome measures (KOOS, Lysholm scale, and short form-36 health survey) were taken pre-surgery and one year later. They found that moderate to full compliant patients with supervised physiotherapy sessions improve their outcome measures and chances of returning to sport. With the decision regarding home-based physiotherapy or supervised physiotherapy session the systematic review by Andrade et al suggested that the prescription of intervention depends on the individual patient. Intensive supervised physiotherapy might be indicated in some patients, but minimal supervision might be indicated for patients who are motivated or live far. They concluded that a home-based programme with added supervised sessions is recommended (Andrade *et al.*, 2020). This was also supported in a more recent prospective observation study by Rhim et al (2021) who compared the functional outcomes at six and 12 months between groups that had supervised sessions and home-based intervention. They concluded that the supervised physiotherapy session group had greater improvement in muscle strength, neuromuscular control, and higher patient-reported knee function.

From the literature, it is suggested that supervised physiotherapy sessions are beneficial to the outcomes of post-operative ACL rehabilitation and show better functional outcomes than home-based intervention alone. Home-based intervention as described in the literature is seen as exercise prescription that is followed at home and not as the physiotherapist doing a home visit and treating the patient at home.

3.5.2.9 Treatment modalities used in rehabilitation.

The treatment modalities found in the literature that will be described include continuous passive movement (CPM), neuromuscular electrostimulation, cryotherapy, dry needling, blood flow restriction, and peripheral joint mobilisation.

Some guidance on specific modalities shows positive results when added to existing protocols (Sakane *et al.*, 1999; Wright *et al.*, 2015; Van Melick *et al.*, 2016; Janssen *et al.*, 2018; Baron *et al.*, 2020; Giesche *et al.*, 2020).

Cryotherapy is effective in decreasing post-operative pain (Hart *et al.*, 2014; Kuenze *et al.*, 2017; Filbay and Grindem, 2019; Andrade *et al.*, 2020). According to Kuenze et al the cryotherapy should be applied for 20 min. The systematic review by Andrade et al (2020) suggested that cryotherapy should only be used for the first 48 hours (Andrade *et al.*, 2020). Filbay and Grindem (2019) suggested that cryotherapy is effective in decreasing pain but is ineffective in reducing effusion around the knee (Filbay and Grindem, 2019)

According to Andrade et al (2020), neuromuscular electrostimulation may be added to the rehabilitation programme depending on the individual's circumstances and the patient's preference. This treatment modality can be added to isometric strengthening in the initial six to eight weeks to re-educate voluntary contraction and increase the strength of quadriceps muscle, but the ideal electrical parameters remain unclear. In the systematic review by van Melick et al (2016) they based their research on four systematic reviews, six random control trails and one prospective cohort study. These studies concluded that adding neuromuscular electrostimulation could improve muscle strength for up to two months after surgical intervention, but the long-term effect on function has not been established yet.

In the randomised single-blinded control trial by Velazquez et al (2017) they found that dry needling in conjunction with a rehabilitation protocol increased the ROM in the short term. In this study, they had 44 patients randomly and equally allocated into two intervention groups. The primary outcome measure was pain intensity, but they also used ROM, stability, and function. The same rehabilitation protocol was applied in both intervention groups, with the addition of one session of dry needling of the vastus

medialis active myofascial trigger point to the experimental group. They found 15 degrees of ROM difference in the two groups after the first week of intervention, but after five weeks there was no clinical difference between the two groups. The limitations mentioned in the study were the sample size and they did not measure post-needling treatment pain. In the study, they said that function was also improved in the short and long term but they did not mention how they measured the function. Thus because of the small sample size the results should be considered with caution.

CPM was originally used as a treatment modality in the post-operative ACL rehabilitation originally described in the article written by De Carlo et al (1992). As the surgical procedures and rehabilitation evolved research regarding CPM showed that it has no short or long-term benefit and is not recommended as a modality in rehabilitation following ACL reconstruction (Wright *et al.*, 2015; Makhni *et al.*, 2016; Andrade *et al.*, 2020).

Blood flow restriction according to Serrano and Serrano (2019) “proposes using partial venous occlusion to induce a local hypoxic response within the exercising muscle which evokes a large neuroendocrine response”. Blood flow restriction takes many forms, some models use pressure gauges to set specific pressures and in some protocols, they use pneumatic devices to monitor the pressure continuously. The blood flow restriction is done in such a way that only venous return is decreased but the arterial blood flow is not affected. The reasoning for using blood flow restriction during exercise is to promote anaerobic metabolism and thus causing hypoxia.
This hypoxic response was found to be similar to exercise at high intensity. It is suggested that this could be of benefit in post-operative rehabilitation to reduce muscle atrophy whiles protecting the surgical graft when there is a restriction of load in OCK and CKC exercises. The systematic review done by Lipker et al (2019) found three randomised controlled trial studies about blood flow restriction and concluded that blood flow restriction and low resistance do not affect the circumference (atrophy) of the quadricep muscle. There is some evidence that shows using blood flow restriction during immobilisation in the early stage of rehabilitation might have some positive effect on the atrophy of the quadricep muscle. The benefit versus the cost and risk needed more evaluation. In a more recent randomised controlled trial by Baron et al (2020), they added blood flow restriction to four groups of exercises. This addition did not increase muscle strength, volume or activation in any of the exercise groups.

Regarding peripheral joint mobilisation of the knee joint as a treatment technique for post-operative ACL rehabilitation only one study was found. The experimental study evaluated the effect of repeated anterior tibiofemoral glides on the extension eight weeks post-operatively. This study found that the mobilisation increases the knee extension ROM, but this decreased again after a ten-minute rest period. They concluded that although glide mobilisation techniques are common in physiotherapy treatment to increase ROM there is limited evidence in the literature to support their efficacy (Hunt *et al.*, 2010).

Some specific modalities showed positive results when added to existing rehabilitation protocols. These include cryotherapy, neuromuscular electrostimulation, dry needling, and peripheral joint mobilisation. The use of blood flow restriction is inconclusive but and should be caution. According to the literature, there is no benefit with the use of CPM.

1.13.3.10 Types of exercises for post-operative ACL rehabilitation

The aim of exercises in the first six weeks of post-operative ACL rehabilitation is to initiate quadricep strength, decrease muscle atrophy and increase neuromuscular activation (Pottkotter et al., 2020; Vidmar et al., 2020). The systematic review by Andrade et al (2020) described suggestions of what exercises should be included in exercise programmes post-operative ACL rehabilitation. The exercise programme should include immediate mobilisation with active and passive ROM exercises, isometric exercises within the first-week post-operatively and the progress to concentric and eccentric exercises of muscles that contribute to the mobility and stability of the knee joint (gastrocnemius, hamstring, quadricep, adductors and gluteus medias). For the first four weeks, close kinetic chain exercises should be started and OKC exercises in a ROM from 45 degrees of knee flexion to 90 degrees of knee flexion can be added thereafter.

Knee mobilisation

Concerning when passive and active ROM should be started Cristiani et al (2021) started with active and passive knee ROM in both the control and intervention groups within the first six weeks of rehabilitation to regain extension ROM. Andrade et al suggest immediate mobilisation to increase ROM within the first week post-operatively to decrease pain and prevent extension loss (Andrade *et al.*, 2020)

According to the protocol for the systematic review by Ektas et al (2019), loss of extension is one of the complications after ACL reconstruction. A loss as small as five degrees could lead to abnormal biomechanics that affects the gait pattern and the ability to climb stairs (Noll *et al.*, 2015). That in turn, can lead to re-rupturing of the ligament, revision surgery or increased risk for the development of osteoarthritis (Ektas *et al.*, 2019). In the cohort study by Noll et al (2015) they found a correlation between the side-to-side knee extension difference at four and 12 weeks post-operatively. The side -to side knee extension is the comparison of non-operated leg extension to the operated leg. The protocol described in the study included active and passive ROM exercises three times a day until symmetrical knee extension was obtained. They concluded that knee extension ROM at four weeks was a good indicator of regaining knee extension ROM in the long run and should be used as a goal initially to prevent extension loss. For this reason, it is important to regain knee extension as soon as possible. Similar findings were found by Ekstas et al (2019), that suggested that the degree of extension loss at four weeks is strongly related to loss of extension ROM at 12 weeks post-operatively.

Isometric exercises

The randomised study by Shaw et al (2005) evaluated the quadricep muscle strength of 103 patients. They included straight-leg raises and isometric quadricep contraction directly post-operatively in the study group. These exercises were excluded from the control group. After two weeks the two groups continued with the same exercise programme. They found no significant difference in muscle strength between the two groups during the six-week follow-up. But the patients in the study group showed a greater improvement in flexion and extension ROM compared to the control group at one-month post-operatively (Shaw, Williams and Chipchase, 2005). In the

rehabilitation protocol by Yabroudi and Irrgang in 2013, they suggested that isometric exercises should be started in the first four to six weeks post-operatively. The isometric quadriceps exercise aims to preserve quadriceps muscle function. This is achieved by the superior translation of the patella that would aid with the straight leg raise exercises (Yabroudi and Irrgang, 2013).

Eccentric exercises

The systematic review by Gokeler et al (2014) specifically looked at the quadriceps muscle function post ACL reconstruction. They concluded that quadriceps strength improves the most with the application of eccentric exercises. The question was when should eccentric exercises be introduced into the exercise programme? This question was answered in the research report written by Gerber et al 2009. They examined the effect of adding progressive eccentric exercises at three weeks post-operatively. With evaluation at the one-year follow up the muscle volume and strength of the experimental group exceeded that of the group that followed a more standardised exercise programme.

Open and Closed kinetic chain exercises

When it comes to the prescription of OCK and CKC exercises there is still no consensus in the literature. According to Thomas et al (2013), it was found that OKC exercises cause increased anterior shear force on the knee and could possibly have a negative impact on the healing of the graft. But OKC exercises are effective in minimising quadricep muscle wasting and improving muscle strength. They suggested that more studies are required to evaluate the safety of these exercises in post-operative rehabilitation of ACL injuries (Thomas *et al.*, 2013). The systematic review by Wright et al (2015) indicated that OKC exercises started after six weeks improved muscle strength without increasing laxity of the graft. In contrast, Andrade et al (2020) suggested that CKC exercises should be emphasised in the early stage of rehabilitation and OKC exercises within ROM of 45 degrees and 90 degrees can start as soon as 4 weeks post-operatively. In the systematic review by Nelson et al (2021) they only looked at the effect of OCK and CKC exercises started eight to 12 weeks post-operatively on the laxity of the knee joint They suggested that both OCK and CKC exercises could be started two to three months post-operatively without affecting the

laxity of the ACL ligament. They suggest that more studies should be done to evaluate the effect of early addition of OCK exercises in post-operative ACL the rehabilitation.

From the literature, we can conclude that the aim of exercises during the first six weeks of post-operative ACL rehabilitation is to initiate quadricep strength, decrease muscle atrophy and increase neuromuscular activation. To achieve this mobilisation should be started immediately post-operatively. Active and passive ROM and isometric exercises should be started within the first six weeks with the aim of full knee extension by week four. Progressive eccentric quadricep exercises should be started three weeks post-operatively. Evidence regards OKC and CKC exercises are conflicting, and more research is required to establish when the addition of these exercises will be the most beneficial for post-operative ACL rehabilitation.

1.13.3.11 Current Outcome measures used to assess post-operative ACL rehabilitation.

The outcome measures used for pain, the use of the numerical pain scale and visual analogue scale were suggested (Janssen et al., 2018; Andrade et al., 2020). For ROM assessment, measurements taken with a goniometer should be used as a measurable outcome (Ektas et al., 2019). The strength of the muscles can be measured with the use of isometric quadricep strength testing (Janssen et al., 2018; Pottkotter et al., 2020) and with the help of the biodex machine (Vidmar et al., 2020). Concerning muscle atrophy measuring the quadricep circumference could be effective (Baron et al., 2020). Functional testing found in the literature included the single leg hop test *(Janssen* et al*., 2018; Andrade* et al*., 2020)* and the triple hop and cross-over hop test (Wright et al., 2008a). Knee stability is assessed with the use of the Anterior drawer test *(Musahl* et al*., 2012; Andrade* et al*., 2020)*. The patient reported function include: KOOS *(Andrade* et al*., 2020; Pottkotter* et al*., 2020)*, International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC) *(Janssen* et al*., 2018; Andrade* et al*., 2020; Pottkotter* et al*., 2020)* and the Lysholm knee scores (Janssen et al., 2018; Naik, Das and Kamat, 2019).

In conclusion, the outcome measures can be grouped according to pain, strength, knee stability and patient-reported functional outcomes. The outcome measures used to

measure pain are the numerical pain scale and visual analogue scale. Strength is objectively measured with the use of isometric quadricep strength testing, functional testing, and knee ligament stability is tested using the anterior drawer test. The patient-reported function scales used in the literature include KOOS and Lysholm knee scores.

1.13.3.12 Summary:

The function of the ACL is to protect the knee from rotational loads and anterior tibial translation though its ROM and in WB (Sakane *et al.*, 1999). ACL injuries occur more often due to non-contact injuries and the mechanism of injury usually includes hyperextension of the knee or a sudden change in moving direction, irrespective of the intrinsic and extrinsic factors that may be present.

The motivation for ACL repair using surgical intervention mentioned in the literature includes recovering stability of the knee joint to prevent injury to other ligaments and the meniscus and cartilage of the knee and helping the patients to return to the preinjury level of sport (Ardern *et al.*, 2011). Complications following ACL reconstruction include deep vein thrombosis, surgical site infection, graft rupture, complex regional pain syndrome, stiffness of the knee, weakness of the quadricep muscle, patellofemoral problems and loss of knee extension (Shelbourne, Klootwyk and DeCarlo, Acevedo *et al.*, 2014; Bordes *et al.*, 2017; Samuelsen *et al.*, 2017). The potential long-term (secondary) complications associated with ACL injury include chronic knee instability, meniscus tear, cartilage injury and osteoarthritis (Acevedo *et al.*, 2014). With regards to post-operative physiotherapy management, it was found that there is a great variety of protocols described in the literature (Eitzen *et al.*, 2010; Yabroudi and Irrgang, 2013; Makhni *et al.*, 2016; Cristiani *et al.*, 2021).

When looking closer to specific protocols regarding accelerated vs non-accelerated protocols, the definition of these protocols was described as follows: The accelerated rehabilitation includes the following: Immediate WB, early unrestricted progressive ROM and gaining knee extension. While a non-accelerated programme includes immobilisation for the first two weeks, with progressive ROM only after the stability of the ACL graft is determined, NWB mobilisation with progression to FWB six weeks post-operatively.

With regards to when rehabilitation should start it was suggested that rehabilitation should be started preoperatively as this could help to decrease swelling, restore ROM, and improve muscle strength to prevent post-operative complications like loss of ROM, patellofemoral pain, and muscle weakness.

Regarding the WB protocol, it is suggested in the literature that the patients should progress to FWB as soon as it can be tolerated but should be done safely to prevent complications like joint laxity and bone tunnel enlargement. Protective bracing post-operatively is not recommended.

Obermeier et al (2018) suggested that rapid recovery and return to function happens mostly within the first month post-operatively, and according to Andrade et al (2020) patients can return to heavy activity and labour within a minimum of three months. The return to sport time frame in the literature varies and ranges from five to nine months post-operatively. It is important not to base the decision on return to sport on a specific time frame but rather on criteria that include clinical evaluation, functional evaluation, and psychological assessment. From the literature, it is suggested that supervised physiotherapy sessions are beneficial to the outcomes of post-operative ACL rehabilitation and show better functional outcomes than home-based intervention alone.

When looking more specifically at the treatment modalities that physiotherapists use during treatment, some modalities show positive results when added to existing rehabilitation protocols. These include cryotherapy, neuromuscular electrostimulation, dry needling, and peripheral joint mobilisation. According to the literature, there is no benefit with the use of CPM.

Another component in physiotherapy treatment post-operatively is exercise prescription. The aim of exercises in the first six weeks of post-operative ACL rehabilitation is to initiate quadricep strength, decrease muscle atrophy and increase neuromuscular activation. To achieve this, mobilisation should be started immediately post-operatively. Active and passive ROM and isometric exercises should be started within the first six weeks with the aim of full knee extension by week four. Progressive eccentric quadricep exercises should be started at 3 weeks post-operatively.

To be able to quantify the results of rehabilitation it is important to use measurable outcomes. From the literature, outcome measures can be grouped according to pain, strength, knee stability and patient-reported functional outcomes. The outcome measures used to measure pain are the numerical pain scale and visual analogue scale. Strength is objectively measured with the use of isometric quadricep strength testing and functional testing. The knee ligament stability is measured with the anterior drawer test. The patient-reported function scales used in the literature include KOOS and Lysholm knee scores.

From the literature review, we can conclude that post-operative rehabilitation is a very important part of the success of the surgical intervention and contributes to the patient's return to function and sport. In Chapter 3 the methodology of the research report will be discussed.

Chapter 2 Methods

2.1 Study Design

The study was a quantitative cross-sectional study using a self-administered questionnaire.

2.2 Study Setting

The participants included in this study were qualified physiotherapists in Gauteng, South Africa that do post-operative ACL rehabilitation.

2.3 Participants

2.3.1 Source of Participants

The source of participants used in this study were all qualified physiotherapists in Gauteng registered with the South African Society of Physiotherapy (SASP) and the Physiotherapy Association of South Africa (PASA).

2.3.2 Sample Size

In the current HPCSA database, there are 8826 registered physiotherapists in South Africa and 3616 of these work in Gauteng. Of these 8826 physiotherapists, 4000 are registered with the SASP and 2966 are registered with PASA. The SASP and PASA were contacted to find out how many active members they have in Gauteng. The SASP has 1801 physiotherapists working in Gauteng and PASA has 120. This sample includes all physiotherapists with different specialities. Due to this, it was difficult to establish a correct response rate because the exact number of physiotherapists that work with post-operative ACL rehabilitation patients cannot accurately be established.

2.3.3 Sample Selection

A sample of convenience was used for data collection. All qualified physiotherapists in Gauteng registered with SASP and PASA that do post-operative ACL rehabilitation were included in the study.

2.3.3.1 Inclusion Criteria

All physiotherapists registered with SASP and PASA that work and live in Gauteng with post-operative ACL rehabilitation and have access to social media linked to these organisations.

2.3.3.2 Exclusion Criteria

The exclusion criteria included all the physiotherapists' responses related to protocols for reconstructive surgeries related to the knee, which includes ACL surgery with meniscus repair or multiple ligament injuries. The other exclusion criteria for this study were all physiotherapists working outside of Gauteng province.

2.4 Instrumentation and Outcome Measures

2.4.1 Self-developed Questionnaire

A self-designed questionnaire was developed for this study. The questionnaire was developed with the guidance of systematic reviews by Andrade et al (2020), Filbay and Grindem (2019), and Wright et al (2008a and b). These articles outline the different treatment strategies for post-operative ACL rehabilitation in current literature. The different components include suggestions regarding the commencement of rehabilitation, WB restriction, the use of post-operative bracing, ROM restriction, exercise prescription in the first six weeks, use of other modalities, and outcome measures that are useful in the assessment of patients and expected return to function and sport.

The questionnaire comprised of three sections: Part 1 which captured the demographic information, part 2 captured specific questions regarding ACL rehabilitation protocol and part 3 captured questions about physiotherapy goals and outcome measures.

2.4.2 Validity of questionnaire

To establish the content validity, five experts (academic and clinical experts, with more than five years' experience) involved with the management of post-operative ACL rehabilitation were invited to validate the content of the questionnaire.

The panel of experts originally selected for the validation of the questionnaire included: Three academics with PhD and masters in physiotherapy, and two clinicians with more than 10 years' experience working with post-operative ACL rehabilitation. Of the five experts only two responded as the remaining three experts of the panel (One academic and two clinicians) were unable to assist with the validation of the questionnaire. On 31 October 2021, three other clinicians were contacted for the pilot study. These experts included an academic with a master's degree in physiotherapy and two clinicians, one with a master's degree in physiotherapy and the other with 12 years of experience working with post-operative ACL rehabilitation patients.

2.5 Procedure

2.5.1 Pilot Study

The pilot study aimed to evaluate the self-developed questionnaire against the aim and objectives of the study. The panel of experts were asked to give feedback about the questionnaire. They were required to answer the following:

1. Is the content relevant?
2. Are the questions clear?
3. Do the questions capture the topic of ACL rehabilitation effectively, according to the aims and objectives of the study?
4. Any suggestions to add to the content of the questionnaire

The results from the panel of experts were summarised in a Microsoft Word document. A short list of corrections and suggestions was compiled from the panel of experts' comments and inputs. The suggestions included adding the definition of the accelerated and non-accelerated protocol, return to function and return to sport. Some of the corrections made included: adjusting the time frame so that it reads correctly, for example, zero to six weeks instead of zero to five weeks. It was also suggested that an option 'other' with a section to elaborate, needed to be added to the questions list.

After careful consideration of the experts' comments and suggestions, the questionnaire was adapted to include their suggestions. The completed version of the questionnaire was then sent again to the experts for final validation. One expert commented on the time spent completing the questionnaire as it took five minutes to complete the questionnaire.

2.5.2 Main Study

The questionnaire was loaded on REDcap (a secure web application for building and managing online surveys and databases). Those who consented to participate in the survey continued to complete the survey. The link with introduction, explanation, ethical approval and consent to participate was sent to the SASP and PASA for distribution to their members. PASA sent the content to their members on 15 December 2021 and a reminder again on 15 January 2022. The SASP sent the questionnaire to their members in January 2022 and according to their rules regarding surveys, they were unable to send a reminder to their members again.

An application to the ethics committee was sent on the 9th of March to request a change in the recruitment process due to the poor response rate using the databases of PASA and SASP. The change requested was to place an advertisement on social media that included WhatsApp, Facebook, and Twitter to invite physiotherapists to participate in this study. This was approved on 14 April 2022. The advertisement was sent via WhatsApp to physiotherapy groups in Gauteng. A request was emailed to SASP to place the advertisement on SASP's social media platforms. After the request was approved it was placed on Facebook on 11 May 2022. The data collection period ended on the 27th of May 2022. Thus, the total data collection period was six months.

2.6 Ethical Considerations

Ethical clearance was given by the University of the Witwatersrand Human Research Ethics Committee, faculty of health Science on 23 August 2021.

With a self-reported questionnaire, it is important to consider the confidentiality of the participants' information. This online survey was accessed using a REDcap link that did not require the participants to share any personal information. The link was sent to SASP and PASA and they distributed it to their members. The PASA and SASP database is strictly confidential. According to POPI act they are not allowed to share this information without written consent. The other consideration is informed consent for participation. Participants confirmed their consent via the REDcap link.
As all survey participants were anonymous, thus there is no impact on POPIA legislation.

2.7 Data Reduction

After the completion of data collection on 27 May 2022, the data was exported from REDcap to Microsoft Excel. In the Excel spreadsheet, the incomplete responses and responses from provinces other than Gauteng were filtered out from the master data.

2.8 Statistical Analysis

The data for the different questions of the questionnaire were placed in separate sheets and 20 pivot tables were used to summarise and calculate statistical data points. From these pivot tables, the percentages, means, and averages were calculated for use in the research report as. Table 3.1 outlines the objective, types of data and descriptive stats that will be used in the study.

Table 2.1: Statistical analysis

Objectives	Type of data	Descriptive stats
Demographic information	Continuous	Frequencies and percentages
1. To determine the number of physiotherapists that use an accelerated programme and non-accelerated protocol.	Categorical	Frequencies and percentages
2. To determine the following rehabilitation goals post ACL surgery: • If rehabilitation starts preoperatively or post-operatively • The WB protocols • The frequency of use of protective bracing • When patients return to normal function • When patients return to sport	Categorical	Frequencies and percentages
3. To determine the commonly used physiotherapy management strategies, modalities, and exercise prescription in the first six weeks of post-operative ACL rehabilitation	Categorical	Frequencies and percentages
4. To determine the outcome measures used in post-operative ACL repair rehabilitation	Categorical	Frequencies and percentages

The results of the study will be presented next, in chapter four.

Chapter 3 Results

The study aimed to determine the management strategy and treatment modalities currently used by physiotherapists in post-operative ACL rehabilitation, in Gauteng, South Africa. This chapter will present the results of the study. The results will be presented as follows:

- Demographic information
- Accelerated vs non- accelerated programme (objective 1)
- Rehabilitation goals post ACL surgery (objective 2)
    - If rehabilitation starts preoperatively or post-operatively
    - The WB protocol
    - The frequency of use of protective bracing
    - When patients return to normal function
    - When patient s return to sport
- Physiotherapy management (objective 3)
- Outcome measures used (objective 4)

A total of 120 physiotherapists accessed the questionnaire on REDcap. Of these 120, 22 responses were incomplete. From the remaining 98, 42 responses to the questionnaire were excluded because the participants were not in the Gauteng province. The total number of completed questionnaires that could be analysed from physiotherapists in Gauteng was 56. Only 46.6 % of the responses could be used for the data analysis.

Figure 4.1 outlines the process of data collection.

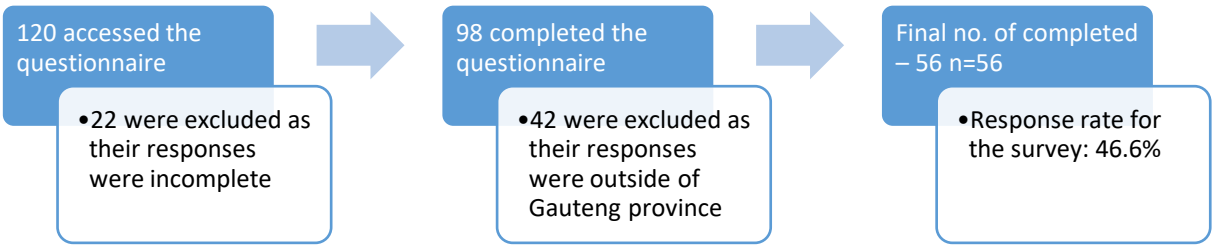

Figure 4.1 outlines the process of data collection

3.1 Results of Part one of the questionnaire: Demographic information about participants

The average age for the physiotherapists that completed the survey was 35.8 years old. The participants' ages ranged from 25 to 60 years.

The average number of years in practice for the physiotherapists that completed the survey was 12,6 years. The range of experience was from one year in practice to 30 years in practice.

The average number of years that the participants had been working with post-operative ACL rehabilitation was 10 years. The range was one year to 30 years of work experience with post-operative ACL rehabilitation.

3.1.1 Post-graduate courses attended.

Table 4.1: Postgraduate courses attended (n=71)

Which postgraduate courses have you completed?		
Courses	**Frequency**	**Percentage**
Orthopaedic manipulative therapy (OMT)	**22**	**31%**
Other	18	25%
ACL rehabilitation courses	15	21%
None	6	8%
Sport and exercise therapy (SPT)	5	7%
Master in OMT	3	4%
Master in SPT	2	3%
PhD	0	0%
Total	**71**	100%

Participants had the opportunity to select more than one option.

Table 4.1 outlines the postgraduate courses done by the participants. The participants were allowed to select more than one option. Most participants (31%) had completed the OMT course. The OMT course is an evidence-based course presented by the SASP. The curriculum covers areas of biopsychosocial management of patients with neuromusculoskeletal pain and dysfunction and complies with the standards of the International Federation of Manipulative Physiotherapy (IFOMPT). The “Other” option responses included courses like:

- “Completed 2-3 courses on the rehab of ACL Injuries”
- “Online and refresher, strapping, weekend courses. Also offered by Biokineticist”
- “International online course by Mick Hughes.” He is a clinical physiotherapist in Australia that works in the field of ACL rehabilitation and is a co-founder of an education group called Learn.Physio that presents lectures about ACL rehabilitation.
- “Clinical solutions paper courses Sports injury courses”
- “General ACL rehab courses “
- “Peer courses with orthopaedic surgeons and specialist Physiotherapists”
- “ACL rehab Continued professional development articles”

- “United Kingdom based courses”
- “Physiopedia online courses”
- “Rosebank sports clinic series: Sports injuries”
- “Watching live surgery and then had a workshop with the surgeon, physiotherapist and Biokineticist

3.2 Results of part two of the questionnaire: ACL rehabilitation protocol

3.2.1 To determine the number of physiotherapists that use an accelerated and non-accelerated protocol.

Table 4.2: Number of Physiotherapists using the accelerated and non-accelerated ACL rehabilitation protocols (n=56)

What protocol do you use for the rehabilitation of patients that had an ACL repair?		
Protocol	**Frequency (percentage)**	**Alignment to definition Frequency (percentage)**
Accelerated	**39 (70%)**	9 (20%)
Non-accelerated	13 (23%)	1 (8%)
Other	4 (7%)	
Grand Total	**56 (100%)**	

Table 4.2 outlines how many physiotherapists use accelerated protocol and non-accelerated protocol and the alignment of responses to the definition of accelerated and non-accelerated protocol given in the questionnaire.

Most of the participants responded that they follow accelerated protocols for ACL rehabilitation. The participants’ option ‘other’ included the following:

- “Depending on the surgeon ad graft used I have rehabilitation using either one or the other protocol”.
- “Protocol is used as a guideline. Patients are adjusted accordingly based on their progression within the rehabilitation process. That is if progression criteria are met earlier than expected then the patient is accelerated and if not, the patient is not accelerated. Factors such as the surgical procedure used, and the surgeon's advice play a role too in the decision making regarding the type of protocol used”
- “Accelerated is my preference, but surgeons might specify non-accelerated”.

- “Depends on surgeon - have different protocols”

3.2.2 To determine if rehabilitation starts preoperatively or post-operatively

Table 4.3: Number of physiotherapists starting rehabilitation preoperatively and post-operatively (n=56)

Count of When does rehabilitation start?		
Protocol	**Frequency**	**Percentage**
Post-Operative	**37**	**66%**
Pre-Operative	19	34%
Grand Total	**56**	**100%**

Table 4.3 outlines how many physiotherapists start rehabilitation pre-operatively and post-operatively. Most participants start with rehabilitation post-operatively.

3.2.3 To determine the WB protocol

Table 4.4: WB regime 0-6 weeks (n=56)

What weight-bearing restriction do you have for post-operative ACL patients from 0-6 Weeks?		
Protocol	**Frequency**	**Percentage**
FWB as Soon as Pain Allows	**31**	**55%**
	20	36%
Other	4	7%
NWB	1	2%
Grand Total	**56**	**100%**

Table 4.4 depicts the weight-bearing regime followed by the participants. The options ‘other’ included:

- “PWB for 2 weeks, then with FWB brace to 6 weeks”
- “WB depending on surgical intervention, surgeons’ recommendation and as pain allows”
- “PWB for 2-4 weeks then as tolerated according to pain”
- “0-2 weeks PWB, 2-6 FWB”

3.2.4 To determine the frequency of use of protective bracing

Table 4.5 :ROM brace prescription protocol (n=56)

Use of a ROM brace post-operatively		
Protocol	**Frequency**	**Percentage**
0-2 Weeks	2	4%
2-4 Weeks	6	11%
4-6 Weeks	**33**	**59%**
6-12 Weeks	2	4%
No ROM brace	10	18%
Other	3	5%
Total	**56**	100%

Table 4.5 depicts the ROM brace prescription protocols post-operatively. The majority 59%, used the ROM brace for four to six weeks. The options 'other' included:

- "Mostly no brace unless surgeon wants more stability in the initial weeks".
- "Surgeon dependent. One Surgeon does not use a brace at all. Others use it for up to 6 weeks".
- "Sometimes dependent on surgeon. If it is my preference, it is patient dependent regarding biomechanics and movement control rather than a specific time".

3.2.5 To determine when patients return to normal function

Table 4.6: When patients return to normal function (n=56)

Return to normal function		
Protocol	**Frequency**	**Percentage**
0-6 Weeks	6	11%
12-18 Weeks	19	34%
6-12 Weeks	**22**	**39%**
Determined by functional test	9	16%
Grand Total	**56**	100%

Table 4.6 depicts when patients return to normal function according to the participants' protocols. The option ‘functional test’ included:

- “Hop test, single leg rise”
- “ROM, stability. strength, agility”
- “Single leg hop, and single leg squat”
- “Quadriceps strength, Full ROM Star excursion balance”
- “Vestibular balance test, single leg Hop test, Triple hop test, crossover hop test, side hop test, single leg rise test”
- “Dependent on the functional level or sport participation”
- “Patient dependant”

3.2.6 To determine when the patient return to sport

Table 4.7: When do the patients return to sport (n=56)

Return to sport		
Protocol	**Frequency**	**Percentage**
0-6 Months	4	7%
6-9 Months	**22**	**39%**
9-12 Months	16	29%
Other	3	5%
Return to sport is determined by functional test	11	20%
Total	**56**	100%

Table 4.7 depicts when patients return to sport according to the participants’ rehabilitation protocols. The option ‘functional test’ included:

- “Vertical jump, stairs running”
- “Not one specific test - but an example is hop height, hop length, hop over 6m”
- “Single leg hops for distance”
- “Appropriate for the type of sport, ROM, stability, strength, agility”
- “Sport-specific assessment”
- “Multi direction hop test and quadricep strength”
- “Load capacity protocol, position-specific return to run and return to contact protocol. Testing such as jump test variations, strength test variations”

- “Biokinetics biodex assessment and programme”
- “Dependent on the functional level or sport participation”
- “Determined by the type of sport”

3.3 Results of part three of the questionnaire: Exercise programme

3.3.1 Physiotherapy strategy used to treat patient post-operatively

Table 4.8: Physiotherapy strategy used post-operatively (n=56)

Physiotherapy strategy to treat patients post ACL repair		
Physiotherapy intervention	**Frequency**	**Percentage**
Weekly Physiotherapy Treatment and Home Exercises	**41**	**73%**
Biweekly Physiotherapy Treatment and Home Exercises	8	14%
Other	6	11%
Home-Based Programme with Exercises	1	2%
Total	**56**	100%

Table 4.8 depicts physiotherapy strategy post-operatively. Most participants treat the patients weekly and this includes a home exercise programme. The options ‘other’ included:

- “Depends on need and patient finance. All patients get a home exercise programme. Referral to local physio. Ideally weekly and home exercises”
- “Due to my association with a sports team, I can see the patient daily to monitor and facilitate treatment and exercises”
- “two-week post-op outpatient session, 1-2 weekly progressed to 2-3 or even 4 until discharge”

3.3.2 Modalities used by physiotherapists to treat patients post-operatively.

Table 4.9: The modalities used by physiotherapists to treat patients post-operatively (n=202)

Modalities used to treat patients post-operatively		
Modality	**Frequency**	**Percentage**
Myofascial Release	**41**	**73%**
Peripheral manual therapy	35	63%
Massage	32	57%
Cryotherapy	19	34%
Neuromuscular stimulation	18	32%
Ultrasound	14	25%
Dry needling	13	23%
Other	13	23%
CPM	8	14%
Laser	5	9%
Blood flow restriction	4	7%
Total	202	100%

Participants had the opportunity to select more than one option

Table 4.9 depicts modalities used by physiotherapists to treat their patients post-operatively. The participants could select more than one option thus the 202 total. Most physiotherapists treat their patients with myofascial release. The options 'other' included:

- Joint mobilisations and Muscle energy techniques
- Mobilization of the knee and Patella-femoral joint
- Exercise therapy and Proprioceptive Neuromuscular Facilitation (PNF)
- Interferential therapy

3.3.1 Exercise prescription: When do you start with the following exercises?

Table 4.10:Summary of exercise prescription in post-operative ACL rehabilitation

Exercises prescription: When do you start with the following exercises?								
	Isometric	**Eccentric**	**Concentric**	**Cross Training**	**OKC**	**CKC**	**Terminal Locking**	**Full Extension**
Time frame	**Frequency (Percentage)**	**Frequency (Percentage)**	**Frequency (Percentage)**	**Frequency (Percentage)**	**Frequency (Percentage)**	**Frequency (Percentage)**	**Frequency (Percentage)**	**Frequency (Percentage)**
0-1 week	**49 (88%)**	10 (18%)	17 (30%)	2 (4%)	14 (25%)	7 (13%)	**18 (32%)**	**26 (46%)**
1-2 weeks	5 (9%)	8 (14%)	**19 (34%)**	1 (2%)	6 (11%)	**16 (29%)**	9 (16%)	9 (16%)
2-3 weeks	1 (2%)	10 (18%)	12 (21%)	7 (13%)	8 (14%)	12 (21%)	5 (9%)	9 (16%)
3-4 weeks	0 (0%)	**14 (25%)**	5 (9%)	5 (9%)	6 (11%)	9 (16%)	6 (11%)	4 (7%)
4-5 weeks	1 (2%)	4 (7%)	2 (4%)	9 (16%)	7 (13%)	5 (9%)	11 (20%)	4 (7%)
6+ weeks	0 (0%)	10 (18%)	1 (2%)	**32 (57%)**	**15 (27%)**	7 (13%)	7 (13%)	4 (7%)
Total	56 (100%)	56 (100%)	56 (100%)	56 (100%)	56 (100%)	56 (100%)	56 (100%)	56 (100%)

Table 4.10 summarises the frequency regarding when the majority of the participants begin the various exercises in the zero-to-six-week time frame.

Most of the participants indicated that isometric exercises in their exercise prescription start between zero and one week post-operatively (88%), eccentric exercises start between three and four weeks post-operatively (25%), concentric exercises start between one and two weeks post-operatively (34%), cross training starts after six weeks post-operatively (57%), OKC exercises starts after six weeks post-operatively (27%), CKC starts one to two weeks post-operatively (29%), terminal locking starts between zero and one week post-operatively (32%), and full exercises starts between zero and one week post-operatively (46%).

3.3.2 Outcome measures for assessment during post-operative ACL rehabilitation of ACL.

Table 4.11: Outcome measure used during post-operative rehabilitation (n=154)

Which outcome measures do you use?		
Outcome measure	**Frequency**	**Percentage**
ROM	**50**	**32%**
Self-Reported Physical Function	37	24%
Numeric pain scale	25	16%
VAS	22	14%
Anterior Drawer test	11	7%
Other	6	4%
Knee injury and Osteoarthritis Outcome Score	3	2%
Total	154	100%

The participants had the opportunity to select more than one option

Table 4.11 depicts the outcome measures used in the assessment of post-operative ACL rehabilitation. The participants could select more than one option. The options 'other' included:

- "Functional tests - start with squat, progress to lunge and later single leg squat"
- "Hop test, Time up and go test six min walk test"
- "Quality of exercises and function, in other words, control, strength, etc"
- "Kinetic control, strength, and balance"
- "The Melbourne ACL guide"
- "Active Knee extension, gait, lunge, balance, hop tests and running analysis"

In conclusion, most of the participants use an accelerated programme (70%); rehabilitation began post-operatively (66%); FWB commenced soon as pain allowed (55%); ROM braces were used for four to six weeks (59%) post-operatively; ROM progression was set according to the guidelines provided by the attending orthopaedic surgeon (77%); patients returned to normal function between six and 12 weeks (39%). Patients returned to sport six to nine months (39%) following ACL rehabilitation: Patients received weekly physiotherapy treatment and home exercises (73%); the modalities mostly used during treatment included myofascial release (73%), peripheral joint mobilisation and massage (63%) and massage (57%); with regard to exercise prescription isometric exercises most often started between zero and one week post-operatively (88%); eccentric exercises most often started between three to four weeks post-operatively (25%); concentric exercises most often started between one and two weeks post-operatively (34%); cross training exercises most often started after six weeks post-operatively (57%); OKC exercises most often started after six weeks post-operatively (27%); CKC exercises most often started one to two weeks post-operatively (29%); terminal locking exercises often started zero to one weeks post-operatively (32%); full knee exercises often started zero to one weeks post-operatively (46%). the outcome measure used most frequently in post-operative rehabilitation was ROM (32%) followed by self-reported physical function (24%). These results will be discussed in Chapter 5.

Chapter 4 Discussion

The first objective of the study was to determine the number of physiotherapists that use accelerated and non-accelerated protocols in post-operative ACL rehabilitation.

The results indicate that 70% (39) selected the accelerated and 23% (13) selected the non-accelerated protocol. To evaluate the alignment of responses to the definition of the accelerated protocol stated in the questionnaire, the answers regarding WB protocol, ROM progression, and when knee extension exercises start were analysed. 71 % (28) of the participants indicated that their patients start with FWB as soon as pain allows. The responses that selected PWB was then excluded. From the 71% (28) there were only 9 (23%) that met the requirement of “Immediate ROM progression” and one of the participants indicated that they only start with knee extension exercises two to three weeks post-operatively. This would suggest that only 20% (8) of the participants followed an accelerated protocol as described in the literature (Shelbourne, Klootwyk and DeCarlo, 1992; Andrade *et al.*, 2020; Cristiani *et al.*, 2021). Furthermore, only one of the participants followed a non-accelerated protocol as summarised in table 2.1 pg.30 although 13 selected non-accelerated protocol. When comparing the participants’ responses to definition of accelerated and non-accelerated protocol in table 2.1 pg.30, the findings are in agreement with Makhni et al (2016) who suggested that a variety of protocols exist and this causes confusion for therapists (Makhni *et al.*, 2016). In the literature no other studies have been done to compare the number of physiotherapists that use accelerated and non-accelerated protocols in South Africa and globally.

The second objective determined the following rehabilitation goals post ACL surgery: if rehabilitation starts preoperatively or post-operatively; the WB protocol; the frequency of use of protective bracing; when patients return to normal function and when patients return to sport.

From the survey, it was established that 66% (37) of the participants started rehabilitation post-operatively. This is not in line with what was found in the literature. The literature shows that patients have better outcomes if rehabilitation starts preoperatively. (Wilk and Arrigo, 2016; Filbay and Grindem, 2019; Carter *et al.*, 2020; Giesche *et al.*, 2020). Wilk and Arrigo (2016) found that preoperative rehabilitation is

important to prepare the patient physically and psychologically for the surgery, decreasing the risk of post-operative complications and improving the chances of successfully returning to function and sport, and decreasing the risk of re-injury (Wilk and Arrigo, 2016). According to Filbay and Grindem (2019), the goal of preoperative rehabilitation is to decrease swelling, restore ROM, and improve quadricep strength. They found that preoperative rehabilitation benefited patients up to two years post-operatively (Filbay and Grindem, 2019). Similar suggestions were made in the systematic review by Giesche et al (2020) that found that preoperative rehabilitation improved the patient's neuromuscular function and their chances of a return to sport. However, in this study, only six studies were included, and limited databases were searched for research. (Giesche *et al.*, 2020). The systematic review of Carter et al (2020) found that function assessed via the single leg hop distance at 12 weeks were significantly better in patients who had preoperative rehabilitation but found that there were low-quality research to support the suggestion that there could be an improvement in muscle strength, function and return to sport in patients who received preoperative rehabilitation in comparison to patients who did not.

Fifty-five per cent (55%) of the participants' patients mobilised FWB as soon as their pain allowed. This was found to be in line with the current literature. Early WB is encouraged as soon as pain allows (De Carlo and Sell, 1997; Wright *et al.*, 2008b; Adams *et al.*, 2012; Naik, Das and Kamat, 2019; Andrade *et al.*, 2020; Jenkins *et al.*, 2022). The biggest consideration that determined the selection of WB protocol is the stability of the knee post-operatively (Fan *et al.*, 2022). Adams et al. (2012) found that delayed WB and ROM showed poorer subjective and objective outcomes (knee outcome survey) post-operatively however Fan et al (2022) suggests that early WB should be delayed, and the rehabilitation protocol should be carefully selected as it could increase the risk of increased laxity and increase in tunnel diameter of the graft. In my experience as a clinician, WB protocol is prescribed by the operating surgeon and facilitated by the treating physiotherapist.

Fifty-nine per cent (33) of participants reported that their patients use a ROM brace for four to six weeks post-operatively. This is not in accordance with what is found in the literature which suggested that post-operative bracing should not be used for ACL ligament rehabilitation because it increases the amount of quadricep muscle atrophy (Kurtz *et al.*, 2011; Wright *et al.*, 2015; Bordes *et al.*, 2017; Lowe *et al.*, 2017; Naik,

Das and Kamat, 2019; Andrade *et al.*, 2020; Nelson *et al.*, 2021). Bordes et al (2017) suggested that a brace should only be used if the patient has a quadricep activation deficit that stops the knee from moving into terminal locking or if the surgical graft is fragile (Bordes *et al.*, 2017). Similar findings were published in a retrospective cohort study by Naik et al (2019) where they found that rehabilitation without protective bracing can indirectly protect against re-injury by preventing muscle atrophy with the early strengthening of the quadriceps muscle. In the systematic review by Andrade et al (2020) they found that post-operative functional bracing was not supported by scientific evidence and the brace should only be considered when it is a more complex injury and other ligaments are involved (Andrade *et al.*, 2020). Again, in my experience, the prescription of protective bracing post-operatively is usually prescribed by the operating surgeon.

Seventy-seven per cent of the participants reported that they set ROM progression according to the guidelines provided by the orthopaedic surgeon, while 23% indicated that they followed immediate progression without set ROM restrictions. The evidence shows that ROM is progressed immediately post-operatively and this has been the gold standard of treatment for more than two decades (Wright *et al.*, 2015; Andrade *et al.*, 2020). Immediate mobilisation aims to prevent the loss of knee extension ROM (Andrade *et al.*, 2020). Thus, it is important that the physiotherapists start with ROM progression as soon as rehabilitation is started.

From the survey, 39% of patients returned to normal function by 12 weeks post-operatively. Return to normal function in the context of this questionnaire was defined as the patient obtaining a pre-injury level of function in activities of daily living. These activities of daily living included returning to school or work and driving. These results are in line with the findings in the literature (Obermeier *et al.*, 2018; Andrade *et al.*, 2020). In the literature are few studies that focused on the return to function for post-operative ACL rehabilitation patients (Obermeier *et al.*, 2018; Andrade *et al.*, 2020). One of these studies by Obermeier et al (2018) found that most of the patients returned to work by day 11 and to school by day seven, and driving by day 11. It was also suggested by Anadale et al (2020) that physical work should only be started after 12 weeks.

Return to sport in this study referred to the patient returning to his or her sport and performing at or better than the pre-injury level. From the analysis of the results, there is great variance in the expected time of returning to sport, 39% responded that the patients return to sport between six to nine months and 29% suggested that return to sport is between nine and 12 months. This is echoed in the literature where the return to sport time frame varies and ranges from five to nine months post-operatively. (Sherman *et al.*, 2021; Fausett, Reid and Larmer, 2022). According to the Moon guidelines by Wright et at (2015) patients usually return to sport between five to six months post operatively. In contrast, Baron et al (2020) found that the return to sport is usually six to nine months post-operatively. When the participant selected the "determined by functional test" they were prompted to give more detail regarding which functional test they used. The answers included: functional tests that include tick, jump, and hop tests. The evidence suggested that clinical evaluation and functional tests are useful in guiding clinical decision-making regarding return to sport. The literature also indicated that it is important not to base the decision to return to sport on a specific time frame only, but also to include objective criteria for guidance (Andrade *et al.*, 2020; Sherman *et al.*, 2021; Fausett, Reid and Larmer, 2022). In the systematic review by Andrade et al (2020) they suggested that these criteria should include clinical evaluation using KOOS, IKDC or Lysholm scores, functional evaluation via hop test and psychological assessment for readiness to return to sport (Andrade *et al.*, 2020).

The third objective determined the commonly used physiotherapy management strategies, modalities, and exercise prescriptions in the first six weeks of post-operative ACL rehabilitation.

There was great variation in how often patients were followed up in outpatient practices while some patients continued with home-based programmes. The majority (73%) of the participants reported that they treated post-operative ACL rehabilitation patients weekly which included a home exercise programme. In the literature there was no consensus regarding how often patients should receive physiotherapy intervention, however rehabilitation requirements are dependent on the prescription of the individual patient's needs (Andrade *et al.*, 2020). Some patients that struggle with rehabilitation on their own need more sessions compared to the patients that cope better. But overall, it was found that supervised sessions had better results than home-based programmes

and were the recommended approach (Han *et al.*, 2015; Andrade *et al.*, 2020; Rhim *et al.*, 2021).

Regarding treatment modalities used by physiotherapists in the treatment of post-operative ACL rehabilitation, myofascial release (75%), peripheral joint mobilisation (63%), Massage (57%) and cryotherapy (34%) were the most used treatment modalities used by physiotherapy in the study. Other modalities in treatment included neuromuscular stimulation (32%) ultrasound therapy (25%), dry needling (23%), other (23%) followed by CPM (14%), laser (9%), and blood flow restriction (7%). The 'other" modalities included muscle energy techniques, PNF, and interferential therapy.

In a systematic review by Ajimsha and Al-mudahka (2015) they evaluated the effectiveness of myofascial release as a treatment modality. A total of 19 articles were included in this study. The conditions that these studies looked at were plantar heel pain, chronic lateral epicondylitis, chronic lower back pain, venous insufficiency in post-menopausal women, breast cancer, fibromyalgia, tension headache, nonspecific cervical and lumbar pain, temporomandibular joint disorder, and hamstring tightness. From these studies, they found that nine of the studies suggested that myofascial release may be better that no treatment at all and that it might be useful as an add-on to conventional treatment (Ajimsha and Al-mudahka, 2015). This has not been confirmed in studies for post-operative ACL rehabilitation.

The second most used modality according to the survey (35%) is peripheral joint mobilisation. Only one article written by Hunt et al (2010) was found regarding joint mobilisation as a treatment modality for post-operative ACL rehabilitation. This article evaluated the effect of repeated anterior tibiofemoral glides on knee extension. In this study, they identified 12 participants with a knee extension deficit compared to the non-operated knee. They did not specify how much ROM deficit was required to meet the inclusion criteria in the study. These patients followed a standard post-operative protocol that included active and passive knee ROM, strengthening exercises and proprioceptive training. During the first eight weeks of rehabilitation, they added repeated anterior tibiofemoral mobilisation as a treatment technique. They evaluated the immediate effect of repeated anterior tibiofemoral glides on maximum knee extension in the gait cycle and re-evaluated this in the follow-up treatment. They found that anterior tibiofemoral joint glides can decrease the extension deficit ($p<0.05$). In this

study, the extension increased with a mean of two degrees which translated to a 25% improvement in the ROM directly after the application of the technique. The ROM decreased again after 10 min of resting in the seated position. They concluded that although glide mobilisation techniques are common in physiotherapy treatment to increase ROM there is limited evidence in the literature to support their efficacy (Hunt *et al.*, 2010).

Cryotherapy is also a modality that has shown effectiveness in decreasing pain post-operatively and is a modality regularly used by physiotherapists in practice. In the survey, 34% (19) selected cryotherapy as a treatment modality. The evidence indicated that it is a good modality to decrease pain (Hart *et al.*, 2014; Kuenze *et al.*, 2017; Filbay and Grindem, 2019; Andrade *et al.*, 2020) but it does not help with effusion around the knee (Filbay and Grindem, 2019). It is suggested that it should only be used for the first 48 hours post-operatively (Andrade *et al.*, 2020).

Neuromuscular stimulation was most extensively researched from all the modalities (Wright *et al.*, 2015; Andrade *et al.*, 2020) In this study 32% (18) selected neuromuscular stimulation as a treatment modality. From the literature, it was concluded that adding Neuromuscular electrostimulation could improve muscle strength for up to two months after surgical intervention but the long-term effect on function has not been established as yet (Van Melick *et al.*, 2016).

No research was found regarding the effectiveness of massage, laser, ultrasound, and myofascial release in the treatment of post-operative ACL rehabilitation. Hurely and Bearne (2008) suggested that massage is effective in the short-term and long-term management of musculoskeletal conditions. Massage causes cutaneous stimulation that releases endogenous pain modulators and activates larger afferent neurons to inhibit pain via the gate control theory. It also increases circulation, improves muscle tone, and has a placebo response. However, they have also indicated that there is not enough evidence of massage efficacy (Hurley and Bearne, 2008). Low-level laser therapy according to Hurley and Bearne (2008) is only recommended in the treatment of patients with rheumatoid arthritis but not for other musculoskeletal conditions. It was shown that low-level laser in the short term may be effective in the treatment of pain and morning stiffness but did not affect function, ROM and swelling (Hurley and Bearne, 2008). Ultrasound was found to decrease pain and inflammation when applied

to inflamed tissue, and it was suggested that it progressed the inflammatory process to the proliferation stage. In this article, the only evidence of clinical effectiveness was found in the treatment of carpal tunnel and calcific tendonitis of the shoulder (Hurley and Bearne, 2008).

Regarding dry needling as a treatment modality, there is limited research, only one article was found. In the randomised single-blinded control trail by Velazquez et al (2017) they found that dry needling into the quadricep muscle in conjunction with a rehabilitation protocol increases the ROM and function in the short term (Velázquez-Saornil *et al.*, 2017). In this survey, it was found that 23% (13) of participants selected dry needling as a treatment modality. In the systematic review by Rodriguez-Mansilla et al (2016) they evaluated the effectiveness of dry needling to decrease pain and increase ROM. For this study, they used 10 randomised control trails from January 2000 to January 2013. The concluded that dry needling was less effective to increase ROM and decrease pain after three to four weeks compared to non-local acupuncture, laser, manipulation, intramuscular stimulation and lidocaine injection and exercise (Rodríguez-Mansilla *et al.*, 2016). However, the results must be viewed with caution considering the very small sample size included in this study.

Fourteen per cent (8) of the participants selected CPM as a treatment modality. In the literature, CPM is not recommended as a modality in rehabilitation as it shows no short or long-term benefit to rehabilitation (Wright *et al.*, 2015; Makhni *et al.*, 2016; Andrade *et al.*, 2020). In the systematic review by Wright et al (2015) they evaluated six randomised control trails regarding CPM, and they not only found no short or long-term benefit of using CPM but also found that approving the machine use by medical insurance was difficult which increased the cost implications of the machine (Wright *et al.*, 2015).

Blood flow restriction is a new treatment strategy and the most recently added modality (Lipker *et al.*, 2019; Curran *et al.*, 2020). From the survey, it was found that 7% (4) of participants use blood flow restriction as a treatment modality. A study done in 2020 by Baron et al (2020) found that the addition of blood flow restriction did not increase muscle strength, volume or activation in any of the exercise groups (Baron *et al.*, 2020) There is some low level evidence that using blood flow restriction during immobilisation in the early stage of rehabilitation might have some positive effect on the atrophy of

the quadricep muscle but the benefit versus the cost and risk needs more evaluation (Lipker *et al.*, 2019).

The other modalities suggested by the participants included interferential therapy, and muscle energy techniques. No research regarding the use of these modalities in post-operative ACL rehabilitation was found in the literature search but the following was found regarding the modalities in general: Interferential therapy is suggested as a modality for the management of pain via the gate control mechanism and opioid release (Hurley and Bearne, 2008; Fuentes *et al.*, 2010). In the systematic review by Fuentes et al (2010) they evaluated the efficacy of interferential therapy as a modality used in the treatment of musculoskeletal pain. In this study, a total of 20 articles were included about the effect of Interferential therapy on conditions like muscle pain, soft tissue shoulder pain, and post-operative pain. They concluded that interferential therapy on its own was not better than a placebo treatment for pain but as an additional treatment with other interventions like exercise, it was more effective in reducing pain than exercise with a placebo (Fuentes *et al.*, 2010). According to the review by Hurley and Bearne, there is little evidence that shows that Interferential therapy is effective in the treatment of musculoskeletal conditions (Hurley and Bearne, 2008).

In the study by Kaur and Reza (2013) they compared the effect of a 14-day program of muscle energy techniques and eccentric exercise on 40 healthy sedentary college students. The programme was 14 days in total followed by one week of rest and a re-evaluation. The outcome measures included ROM in the active knee extension test and sit and reach test. They found a significant improvement in the active knee extension ROM ($p=0.005$) but with the sit and reach test there was no significant difference between the groups ($p=0.219$). From this study, they found that muscle energy techniques were more effective than eccentric training to increase the flexibility of hamstring muscles in sedentary college students (Kaur and Reza, 2013).

The main findings regarding exercise prescription were: isometric exercises were most often (88%) started between zero and one week post-operatively; eccentric exercises were started between three and four weeks post-operatively (25%); concentric exercises were started between one and two weeks post-operatively (34%); cross training exercises were started after six weeks post-operatively (57%); OKC exercises

were started after six weeks post-operatively (27%); CKC starts one to two weeks post-operatively (29%), terminal locking starts between zero and one week post-operatively (32%), and full knee exercises starts between zero and one week post-operatively (46%). as seen in table 4.12 on pg.66

From the literature, we can conclude that the aim of exercises in the first six weeks of post-operative ACL rehabilitation is to initiate quadricep strength, decrease muscle atrophy and increase neuromuscular activation (Pottkotter et al., 2020; Vidmar et al., 2020). It is important to regain knee extension as soon as possible as a lack of ROM into extension could lead to secondary complications (Noll *et al.*, 2015; Ektas *et al.*, 2019). Isometric exercises should be started within the first six weeks with the aim of full knee extension by week four (Shaw, Williams and Chipchase, 2005; Yabroudi and Irrgang, 2013). Progressive eccentric quadriceps exercises should be started three weeks post-operatively(Gerber *et al.*, 2009; Dingenen *et al.*, 2021). Evidence regards OKC and CKC exercises are conflicting, and more research is required to establish when the addition of these exercises will be the most beneficial for post-operative ACL rehabilitation.

In the study, some responses regarding exercise prescription timelines corresponded with the literature. These timeframes included isometric exercises, eccentric exercises and when joint mobilisation should start. In contrast a variety of responses can be seen regarding OCK and CKC exercises. This was found to be in agreement with the literature where it was suggested that the literature regarding OCK and CKC exercises are conflicting and echoed by Thomas et al (2013) that suggest that there is still no consensus in the literature regarding prescription of OCK and CKC exercises for postoperative ACL rehabilitation (Thomas *et al.*, 2013).

The last objective determined the outcome measures used in post-operative ACL rehabilitation.

Thirty- two per cent (50) of the participants reported using ROM as an outcome measure. This was followed by self-reported physical function with 24% (37), numeric pain scale with 16% (25), visual analogue scale with 14% (22), anterior drawer test

with seven percentage (11), KOOS with two per cent (three) and lastly ‘other’ with seven per cent (11 out of 56). The ‘other’ outcome measures that were mentioned were functional tests like the hop test, the six-minute walk test, kinetic control and balance and running analysis. When comparing the results in the literature it was found that the numerical pain scale and visual analogue scale were used to measure pain (Janssen et al., 2018; Andrade et al., 2020). ROM was used as a measurable outcome (Ektas et al., 2019). The strength of the muscles was measured with the use of isometric quadricep strength testing(Janssen et al., 2018; Pottkotter et al., 2020) and with the help of the biodex machine (Vidmar et al., 2020). Concerning muscle atrophy, it was evaluated by measuring quadricep circumference (Baron et al., 2020). Functional testing found in the literature included the single leg hop test (Janssen *et al.*, 2018; Andrade *et al.*, 2020) and the triple hop and cross-over hop test (Wright et al., 2008a). Knee stability was assessed with the use of the Anterior drawer test (Musahl *et al.*, 2012; Andrade *et al.*, 2020). The patient reported function was assessed with the use of KOOS (Andrade *et al.*, 2020; Pottkotter *et al.*, 2020), IKDC (Janssen *et al.*, 2018; Andrade *et al.*, 2020; Pottkotter *et al.*, 2020) and the Lysholm knee scores (Janssen et al., 2018; Naik, Das and Kamat, 2019). Outcome measures are important to objectively evaluate the outcomes of post-operative ACL rehabilitation patients. Greater guidance is required in practice to use these outcome measures more effectively for the benefit of the patients’ outcomes.

In conclusion, it was found that there is a great variety of interpretations of accelerated and non-accelerated protocols for post-operative ACL rehabilitation. According to the participants, rehabilitation most often starts post-operatively in contrast to the literature that suggests that rehabilitation should start preoperatively. The protocol regarding mobilising FWB as soon as pain allows according to the respondents is in line with what is suggested in the literature. The use of protective bracing is not recommended in the literature but most of the participants indicated that their patients use ROM braces for four to six weeks post-operatively. The estimated time of return to function was in line with the literature but the return to sport varied between six and nine months and nine to 12 months postoperatively. This variation in the time of return to sport was also found in the literature. There is a great variation in how often patients should be followed up and this was echoed in the literature, there was no consensus on how often a patient should receive physiotherapy intervention. Not all modalities used by

physiotherapists have been researched in the treatment of post-operative ACL rehabilitation.

The treatment modalities myofascial release, peripheral joint mobilisation, massage and cryotherapy were the most used treatment modalities used by physiotherapy in the study. Other modalities used in treatment included neuromuscular stimulation, ultrasound therapy, dry needling, CPM, laser, muscle energy techniques, PNF,and interferential therapy. Not all of these modalities have been studied as treatment modalities for post-operative ACL rehabilitation, but some specific modalities showed positive results when added to existing rehabilitation protocols, according to the evidence. These include cryotherapy, neuromuscular electrostimulation, dry needling, and peripheral joint mobilisation. The use of blood flow restriction should be used with caution. According to the literature, there is no benefit with the use of CPM.

The aim of exercises during the first six weeks of post-operative ACL rehabilitation is to initiate quadricep strength, decrease muscle atrophy and increase neuromuscular activation. In this study, exercise prescription timelines vary greatly. Some responses corresponded with the evidence like timeframes for isometric exercises, eccentric exercises and when joint mobilisation should start. In the literature there is no consensus regarding OCK and CKC exercise timeframes, this is echoed in the responses by the participants.

Outcome measures are important to objectively evaluate the outcomes of post-operative ACL rehabilitation patients. In the literature, many outcome measures can be used to assess pain, ROM, strength, stability, and patients' self-reported function. According to the survey most participants use ROM, self-reported physical function, pain scales (VAS and NPS) and anterior drawer test for stability.

Chapter 5 Conclusion and Recommendations

5.1 Conclusion

This study revealed that the majority of participants followed an accelerated protocol (70%) for post-operative ACL rehabilitation. From these responses it was found that the minority participants that selected the accelerated protocol (20%) aligned with the definition of accelerated protocol as defined in table 2.1 pg. 30. The majority of the participants followed protocols with some variety on the described accelerated protocol in the literature possibly suggested by the treating orthopaedic surgeon.

Regarding rehabilitation goals post-operatively that some of the goals were in line with the current literature for example WB protocol and return to function where most of the participants progressed to FWB as soon as pain allows, and patients returned to normal function by 12 weeks post-operatively. But the time frame for commencing rehabilitation and protective bracing did not correspond to the findings in the literature, which suggests that rehabilitation should start preoperatively, and no brace is indicated post-operatively. In our study, there was no consensus about when patients should return to sport, and this was echoed by the literature. But it is important to note that the return to sport should not only be indicated by timeframe but with clinical evaluation, functional evaluation, and psychological assessment for readiness to return to sport.

Concerning physiotherapy management, a variety of modalities were described. Some of the modalities used showed positive results in the literature specifically regarding post-operative ACL rehabilitation. These include cryotherapy, neuromuscular electrostimulation, dry needling, and peripheral joint mobilisation.

When looking specifically at the exercise prescription there is a great variety of timelines for the different exercises. Some correspond with the suggestions from literature, and these include isometric exercises, eccentric exercises, and joint mobilisation. There is no consensus about OCK and CKC exercise prescription.

Outcome measures are important to objectively evaluate the outcomes of post-operative ACL rehabilitation patients. The outcome measures most used by the

participants were ROM and self-reported function. In the literature, a great variety of outcome measures can be found. These outcome measures are used to measure pain (numerical pain scale and visual analogue scale), muscle strength (isometric quadricep strength testing, functional testing), knee stability (anterior drawer test) and patient-reported function scales (KOOS, and Lysholm knee scores). Greater guidance is required in practice to use these outcome measures more effectively for the benefit of the patients' outcomes.

From this, I can conclude that there is a great variety of protocols, modalities and exercise prescription used in post-operative ACL rehabilitation. In my experience as a physiotherapist involved in post-operative rehabilitation, this variety stems from every practice developing their own protocols together with the orthopaedic surgeon they work with and their clinical experience. The aim of post-operative ACL rehabilitation is to return the patients to normal function and sport as soon and safely as possible. The lack of evidence-based protocols, modalities and exercise prescription may lead to a delayed return to sport or independent function or even cause the patients not to return to sport at all.

5.2 Recommendations for Future Research

Good quality research protocols, modalities and exercise prescriptions are needed to improve the effectiveness of post-operative ACL rehabilitation. There is still no consensus about OCK and CKC exercise prescription in the literature and requires further investigation as this is an important component of muscle strengthening and can decrease the time for return to function and return to sport. Further research regarding ROM progression is also needed as this initial part of rehabilitation plays a vital part in prevention of complications like stiffness of the knee. Another component that needs to be researched is the psychological effect that preoperative education has on rehabilitation outcomes.

5.3 Strengths and Limitations

The strengths of the study include the following: This was the first research regarding physiotherapy management of post-operative ACL rehabilitation done in South Africa. The questionnaire evaluated not only single components like the return to sport as seen in other physiotherapy surveys. It included a section which captured the demographic information, a section that captured specific questions regarding rehabilitation protocol and another section that captured questions about physiotherapy goals and outcome measures.

The limitations of the study included a poor response rate to the questionnaire as only one province was surveyed.

Another limitation was that a sample of convenience was used for this study. Even though link to the questionnaire was sent to all the physiotherapists registered with the SASP and PASA in all provinces of South Africa, only Gauteng responses were used. This sample of convenience included all physiotherapists with different special interests, not only ones that work with post-operative ACL rehabilitation thus a specific sample size could not be established.

The survey was very general and did not ask specific details regarding to post-operative ACL rehabilitation protocols, modalities, and exercise prescription. The questionnaire did not take other factors like surgical and psychological effect on rehabilitation into account. When looking at the success of post-operative ACL rehabilitation patients it is important to consider not only the rehabilitation component but also the surgical and psychological considerations. Factors for the surgical intervention include graft placement, mechanical properties of the graft and the biological process of healing (Janssen *et al.*, 2018). Psychologically it is important to evaluate the patients' believes and attitudes about the return to sport (Wright *et al.*, 2008b).

References

Acevedo, R. J. *et al.* (2014) ‘Anterior cruciate ligament injury: Identification of risk factors and prevention strategies’, *Current Sports Medicine Reports*, 13(3), pp. 186–

191. doi: 10.1249/JSR.0000000000000053.

Adams, D. *et al.* (2012) 'Current concepts for anterior cruciate ligament reconstruction: A criterion-based rehabilitation progression', *Journal of Orthopaedic and Sports Physical Therapy*, 42(7), pp. 601–614. doi: 10.2519/jospt.2012.3871.

Ajimsha, M. S. and Al-mudahka, N. R. (2015) 'FASCIA SCIENCE AND CLINICAL APPLICATIONS : SYSTEMATIC REVIEW: Effectiveness of myofascial release : Systematic review of randomized controlled trials', *Journal of Bodywork & Movement Therapies*, 19, pp. 102–112.

Andrade, R. *et al.* (2020) 'How should clinicians rehabilitate patients after ACL reconstruction? A systematic review of clinical practice guidelines (CPGs) with a focus on quality appraisal (AGREE II)', *British Journal of Sports Medicine*, 54(9), pp. 512–519. doi: 10.1136/bjsports-2018-100310.

Aquino, C. F. *et al.* (2021) 'Current clinical practice and return-to-sport criteria after anterior cruciate ligament reconstruction: a survey of Brazilian physical therapists', *Brazilian Journal of Physical Therapy*, 25(3), pp. 242–250. doi: 10.1016/j.bjpt.2020.05.014.

Ardern, C. L. *et al.* (2011) 'Return to the preinjury level of competitive sport after anterior cruciate ligament reconstruction surgery: Two-thirds of patients have not returned by 12 months after surgery', *American Journal of Sports Medicine*, 39(3), pp. 538–543. doi: 10.1177/0363546510384798.

Baron, J. E. *et al.* (2020) 'Perioperative and Postoperative Factors Influence Quadriceps Atrophy and Strength After ACL Reconstruction: A Systematic Review', *Orthopaedic Journal of Sports Medicine*, 8(6), pp. 1–10. doi: 10.1177/2325967120930296.

Beynnon, B. D. *et al.* (2011) 'Accelerated versus nonaccelerated rehabilitation after anterior cruciate ligament reconstruction: A prospective, randomized, double-blind investigation evaluating knee joint laxity using roentgen stereophotogrammetric analysis', *American Journal of Sports Medicine*, 39(12), pp. 2536–2548. doi: 10.1177/0363546511422349.

Boden, B. P. *et al.* (2010) 'Non-contact ACL Injuries: Mechanisms and Risk Factors', *American Academy of Orthopaedic Surgeons*, 18(9), pp. 520–527.

Boden, B. P. and Sheehan, F. T. (2022) 'Mechanism of non-contact ACL injury: OREF Clinical Research Award 2021', *Journal of Orthopaedic Research*, 40(3), pp. 531–540. doi: 10.1002/jor.25257.

Bordes, P. *et al.* (2017) 'No beneficial effect of bracing after anterior cruciate ligament

reconstruction in a cohort of 969 athletes followed in rehabilitation', *Annals of Physical and Rehabilitation Medicine*, 60(4), pp. 230–236. doi: 10.1016/j.rehab.2017.02.001.

De Carlo, M. S. *et al.* (1992) 'Traditional versus accelerated rehabilitation following ACL reconstruction: A one-year follow-up', *Journal of Orthopaedic and Sports Physical Therapy*, 15(6), pp. 309–316. doi: 10.2519/jospt.1992.15.6.309.

De Carlo, M. S. and Sell, K. E. (1997) 'The effects of the number and frequency of physical therapy treatments on selected outcomes of treatment in patients with anterior cruciate ligament reconstruction', *Journal of Orthopaedic and Sports Physical Therapy*, 26(6), pp. 332–339. doi: 10.2519/jospt.1997.26.6.332.

Carter, H. M. *et al.* (2020) 'The effectiveness of preoperative rehabilitation programmes on postoperative outcomes following anterior cruciate ligament (ACL) reconstruction: A systematic review', *BMC Musculoskeletal Disorders*, 21(1), pp. 1–13. doi: 10.1186/s12891-020-03676-6.

Collins, J. E. *et al.* (2013) 'Cumulative incidence of ACL reconstruction after ACL injury in adults: Role of age, sex, and race', *American Journal of Sports Medicine*, 41(3), pp. 544–549. doi: 10.1177/0363546512472042.

Common Knee Injuries - OrthoInfo - AAOS." *Aaos.org*, 2014, orthoinfo.aaos.org/en/diseases--conditions/common-knee-injuries/.

Cristiani, R. *et al.* (2021) 'Autograft type affects muscle strength and hop performance after ACL reconstruction. A randomised controlled trial comparing patellar tendon and hamstring tendon autografts with standard or accelerated rehabilitation', *Knee Surgery, Sports Traumatology, Arthroscopy*, 29(9), pp. 3025–3036. doi: 10.1007/s00167-020-06334-5.

Curran, M. T. *et al.* (2020) 'Blood Flow Restriction Training Applied With High-Intensity Exercise Does Not Improve Quadriceps Muscle Function After Anterior Cruciate Ligament Reconstruction: A Randomized Controlled Trial', *American Journal of Sports Medicine*, 48(4), pp. 825–837. doi: 10.1177/0363546520904008.

Czamara, A. *et al.* (2021) 'The muscle strength of the knee joint after acl reconstruction depends on the number and frequency of supervised physiotherapy visits', *International Journal of Environmental Research and Public Health*, 18(20). doi: 10.3390/ijerph182010588.

Dingenen, B. *et al.* (2021) 'Rehabilitation strategies of Flemish physical therapists before and after anterior cruciate ligament reconstruction: An online survey', *Physical Therapy in Sport*, 49, pp. 68–76. doi: 10.1016/j.ptsp.2021.02.003.

Ebert, J. R. *et al.* (2019) 'Current perspectives of Australian therapists on rehabilitation

and return to sport after anterior cruciate ligament reconstruction: A survey', *Physical Therapy in Sport*, 35, pp. 139–145. doi: 10.1016/j.ptsp.2018.12.004.

Eitzen, I. *et al.* (2010) 'A progressive 5-week exercise therapy program leads to significant improvement in knee function early after anterior cruciate ligament injury', *Journal of Orthopaedic and Sports Physical Therapy*, 40(11), pp. 705–721. doi: 10.2519/jospt.2010.3345.

Ektas, N. *et al.* (2019) 'Recovery of knee extension and incidence of extension deficits following anterior cruciate ligament injury and treatment: A systematic review protocol', *Journal of Orthopaedic Surgery and Research*, 14(1), pp. 1–7. doi: 10.1186/s13018-019-1127-8.

Fan, Z. *et al.* (2022) 'Delayed Versus Accelerated Weight-Bearing Rehabilitation Protocol Following Anterior Cruciate Ligament Reconstruction: a Systematic Review and Meta-Analysis', *Journal of Rehabilitation Medicine*, 54. doi: 10.2340/jrm.v53.1438.

Fausett, W. A., Reid, D. A. and Larmer, P. J. (2022) 'Current perspectives of New Zealand physiotherapists on rehabilitation and return to sport following anterior cruciate ligament reconstruction: A survey', *Physical Therapy in Sport*, 53, pp. 166–172. doi: 10.1016/j.ptsp.2021.10.012.

Filbay, S. R. and Grindem, H. (2019) 'Evidence-based recommendations for the management of anterior cruciate ligament (ACL) rupture', *Best Practice and Research: Clinical Rheumatology*, 33(1), pp. 33–47. doi: 10.1016/j.berh.2019.01.018.

Fuentes, J. P. *et al.* (2010) 'Effectiveness of Interferential current therapy in the management of musculoskeletal pain: A systematic review and meta-analysis', *Physical Therapy*, 90(9), pp. 1219–1238. doi: 10.2522/ptj.20090335.

Gerber, J. P. *et al.* (2009) 'Effects of early progressive eccentric exercise on muscle size and function after anterior cruciate ligament reconstruction: A 1-year follow-up study of a randomized clinical trial', *Physical Therapy*, 89(1), pp. 51–59. doi: 10.2522/ptj.20070189.

Giesche, F. *et al.* (2020) 'Evidence for the effects of prehabilitation before ACL-reconstruction on return to sport-related and self-reported knee function: A systematic review', *PLoS ONE*, 15(10 October), pp. 1–21. doi: 10.1371/journal.pone.0240192.

Gokeler, A. *et al.* (2014) 'Quadriceps function following ACL reconstruction and rehabilitation: Implications for optimisation of current practices', *Knee Surgery, Sports Traumatology, Arthroscopy*, 22(5), pp. 1163–1174. doi: 10.1007/s00167-013-2577-x.

Greenberg, E. M. *et al.* (2018) 'Rehabilitation practice patterns following anterior cruciate ligament reconstruction: A survey of physical therapists', *Journal of*

Orthopaedic and Sports Physical Therapy, 48(10), pp. 801–811. doi: 10.2519/jospt.2018.8264.

Gupta, A. S. *et al.* (2020) 'Sex-Based Differences in Anterior Cruciate Ligament Injuries Among United States High School Soccer Players: An Epidemiological Study', *Orthopaedic Journal of Sports Medicine*, 8(5), pp. 1–8. doi: 10.1177/2325967120919178.

Gupta, P. K. *et al.* (2017) 'Role of accelerated rehabilitation versus standard rehabilitation following anterior cruciate ligament reconstruction using hamstring graft', *Journal of Arthroscopy and Joint Surgery*, 4(2), pp. 89–93. doi: 10.1016/j.jajs.2017.08.003.

Han, F. *et al.* (2015) 'Increased Compliance With Supervised Rehabilitation Improves Functional Outcome and Return to Sport After Anterior Cruciate Ligament Reconstruction in Recreational Athletes', *Orthopaedic Journal of Sports Medicine*, 3(12), pp. 1–8. doi: 10.1177/2325967115620770.

Hart, J. M. *et al.* (2014) 'Quadriceps muscle function after rehabilitation with cryotherapy in patients with anterior cruciate ligament reconstruction', *Journal of Athletic Training*, 49(6), pp. 733–739. doi: 10.4085/1062-6050-49.3.39.

Hewett, T. E. *et al.* (2016) 'Mechanisms, prediction, and prevention of ACL injuries: Cut risk with three sharpened and validated tools', *Journal of Orthopaedic Research*, 34(11), pp. 1843–1855. doi: 10.1002/jor.23414.

Hunt, M. A. *et al.* (2010) 'Effect of anterior tibiofemoral glides on knee extension during gait in patients with decreased range of motion after anterior cruciate ligament reconstruction', *Physiotherapy Canada*, 62(3), pp. 235–241. doi: 10.3138/physio.62.3.235.

Hurley, M. V. and Bearne, L. M. (2008) 'Non-exercise physical therapies for musculoskeletal conditions', *Best Practice and Research: Clinical Rheumatology*, 22(3), pp. 419–433. doi: 10.1016/j.berh.2008.01.001.

Janssen, R. P. A. *et al.* (2018) 'ACL reconstruction with hamstring tendon autograft and accelerated brace-free rehabilitation: A systematic review of clinical outcomes', *BMJ Open Sport and Exercise Medicine*, 4(1). doi: 10.1136/bmjsem-2017-000301.

Jenkins, S. M. *et al.* (2022) 'Rehabilitation After Anterior Cruciate Ligament Injury: Review of Current Literature and Recommendations.', *Current reviews in musculoskeletal medicine*, pp. 170–179. doi: 10.1007/s12178-022-09752-9.

Joseph, A. M. *et al.* (2013) 'A multisport epidemiologic comparison of anterior cruciate ligament injuries in high school athletics', *Journal of Athletic Training*, 48(6), pp. 810–

817. doi: 10.4085/1062-6050-48.6.03.

Kaur, G. and Reza, M. K. (2013) 'Efficacy of Eccentric Training and Muscle Energy Technique on Hamstring Flexibility in Sedentary College Students', *Indian Journal of Physiotherapy and Occupational Therapy - An International Journal*, 7(3), p. 93. doi: 10.5958/j.0973-5674.7.3.072.

Korakakis, V. *et al.* (2021) 'Current perspectives and clinical practice of physiotherapists on assessment, rehabilitation, and return to sport criteria after anterior cruciate ligament injury and reconstruction. An online survey of 538 physiotherapists', *Physical Therapy in Sport*, 52(2021), pp. 103–114. doi: 10.1016/j.ptsp.2021.08.012.

Kuenze, C. M. *et al.* (2017) 'Unilateral quadriceps strengthening with disinhibitory cryotherapy and quadriceps symmetry after anterior cruciate ligament reconstruction', *Journal of Athletic Training*, 52(11), pp. 1010–1018. doi: 10.4085/1062-6050-52.10.13.

Kurtz, S. M. *et al.* (2011) 'International survey of primary and revision total knee replacement', *International Orthopaedics*, 35(12), pp. 1783–1789. doi: 10.1007/s00264-011-1235-5.

Lewis, D. A. *et al.* (2018) 'Comparison of four alternative national universal anterior cruciate ligament injury prevention programme implementation strategies to reduce secondary future medical costs', *British Journal of Sports Medicine*, 52(4), pp. 277–282. doi: 10.1136/bjsports-2016-096667.

Lipker, L. A. *et al.* (2019) 'Blood Flow Restriction Therapy Versus Standard Care for Reducing Quadriceps Atrophy After Anterior Cruciate Ligament Reconstruction', *Journal of sport rehabilitation*, 28(8), pp. 897–901. doi: 10.1123/jsr.2018-0062.

Lowe, W. R. *et al.* (2017) 'Functional bracing after anterior cruciate ligament reconstruction: A systematic review', *Journal of the American Academy of Orthopaedic Surgeons*, 25(3), pp. 239–249. doi: 10.5435/JAAOS-D-15-00710.

Makhni, E. C. *et al.* (2016) 'Quality and Variability of Online Available Physical Therapy Protocols From Academic Orthopaedic Surgery Programs for Anterior Cruciate Ligament Reconstruction', *Arthroscopy - Journal of Arthroscopic and Related Surgery*, 32(8), pp. 1612–1621. doi: 10.1016/j.arthro.2016.01.033.

Marieswaran, M. *et al.* (2018) 'Review Article A Review on Biomechanics of Anterior Cruciate Ligament and Ma[1] M. Marieswaran, I. Jain, B. Garg, V. Sharma, and D. Kalyanasundaram, "Review Article A Review on Biomechanics of Anterior Cruciate Ligament and Materials for Reconstruction,"' 2018.

Markatos, K. *et al.* (2013) 'The anatomy of the ACL and its importance in ACL reconstruction', *European Journal of Orthopaedic Surgery and Traumatology*, 23(7),

pp. 747–752. doi: 10.1007/s00590-012-1079-8.

Mclean, S. G. (2007) 'ACL Injuries: Do We Know the Mechanisms?', 37(2).

Van Melick, N. *et al.* (2016) 'Evidence-based clinical practice update: Practice guidelines for anterior cruciate ligament rehabilitation based on a systematic review and multidisciplinary consensus', *British Journal of Sports Medicine*, 50(24), pp. 1506–1515. doi: 10.1136/bjsports-2015-095898.

Musahl, V. *et al.* (2012) 'Rotatory knee laxity tests and the pivot shift as tools for ACL treatment algorithm', *Knee Surgery, Sports Traumatology, Arthroscopy*, 20(4), pp. 793–800. doi: 10.1007/s00167-011-1857-6.

Naik, A. A., Das, B. and Kamat, Y. D. (2019) 'Avoid post operative bracing to reduce ACL rerupture rates', *European Journal of Orthopaedic Surgery and Traumatology*, 29(8), pp. 1743–1747. doi: 10.1007/s00590-019-02521-4.

Nelson, C. *et al.* (2021) 'Postoperative rehabilitation of anterior cruciate ligament reconstruction: A systematic review', *Sports Medicine and Arthroscopy Review*, 29(2), pp. 63–80. doi: 10.1097/JSA.0000000000000314.

Noll, S. *et al.* (2015) 'Knee extension range of motion at 4 weeks is related to knee extension loss at 12 weeks after anterior cruciate ligament reconstruction', *Orthopaedic Journal of Sports Medicine*, 3(5), pp. 1–6. doi: 10.1177/2325967115583632.

Obermeier, M. C. *et al.* (2018) 'Examination of Early Functional Recovery After ACL Reconstruction: Functional Milestone Achievement and Self-Reported Function', *Sports Health*, 10(4), pp. 345–354. doi: 10.1177/1941738118779762.

Petersen, W. and Tillmann, B. (2002) 'Anatomie und funktion des vorderen kreuzbandes', *Orthopade*, 31(8), pp. 710–718. doi: 10.1007/s00132-002-0330-0.

Pfeifer, C. E. *et al.* (2018) 'Risk Factors Associated With Non-Contact Anterior Cruciate Ligament Injury: a Systematic Review', *International Journal of Sports Physical Therapy*, 13(4), pp. 575–587. doi: 10.26603/ijspt20180575.

Pizzari, T. *et al.* (2013) 'Principles of postoperative anterior cruciate ligament rehabilitation', *Journal of Orthopaedic and Sports Physical Therapy*, 15(6), pp. 938–944. doi: 10.1097/01.jsm.0000188045.06545.ac.

Pottkotter, K. A. *et al.* (2020) 'Timeline of Gains in Quadriceps Strength Symmetry and Patient-Reported Function Early After Acl Reconstruction', *International Journal of Sports Physical Therapy*, 15(6), pp. 995–1005. doi: 10.26603/ijspt20200995.

Rhim, H. C. *et al.* (2021) 'Article supervised rehabilitation may lead to better outcome than home-based rehabilitation up to 1 year after anterior cruciate ligament

reconstruction', *Medicina (Lithuania)*, 57(1), pp. 1–15. doi: 10.3390/medicina57010019.

Rodríguez-Mansilla, J. *et al.* (2016) 'Effectiveness of dry needling on reducing pain intensity in patients with myofascial pain syndrome: a Meta-analysis', *Journal of traditional Chinese medicine = Chung i tsa chih ying wen pan / sponsored by All-China Association of Traditional Chinese Medicine, Academy of Traditional Chinese Medicine*, 36(1), pp. 1–13. doi: 10.1016/s0254-6272(16)30001-2.

Sakane, M. *et al.* (1999) 'Relative contribution of the ACL, MCL, and bony contact to the anterior stability of the knee', *Knee Surgery, Sports Traumatology, Arthroscopy*, 7(2), pp. 93–97. doi: 10.1007/s001670050128.

Samuelsen, B. T. *et al.* (2017) 'Hamstring Autograft versus Patellar Tendon Autograft for ACL Reconstruction: Is There a Difference in Graft Failure Rate? A Meta-analysis of 47,613 Patients', *Clinical Orthopaedics and Related Research*, 475(10), pp. 2459–2468. doi: 10.1007/s11999-017-5278-9.

Serrano, B. and Serrano, J. (2019) 'the Efficacy and Validity of Blood Flow Restriction Training in Clinical and Post-Surgical Populations', *International Journal of Physiotherapy*, 6(5), pp. 155–159. doi: 10.15621/ijphy/2019/v6i5/186836.

Shaw, T., Williams, M. T. and Chipchase, L. S. (2005) 'Do early quadriceps exercises affect the outcome of ACL reconstruction? A randomised controlled trial', *Australian Journal of Physiotherapy*, 51(1), pp. 9–17. doi: 10.1016/S0004-9514(05)70048-9.

Shea, K. G. and Carey, J. L. (2015) 'Management of anterior cruciate ligament injuries: Evidence-based guideline', *Journal of the American Academy of Orthopaedic Surgeons*, 23(5), pp. e1–e5. doi: 10.5435/JAAOS-D-15-00094.

Shelbourne, K. D., Klootwyk, T. E. and DeCarlo, M. S. (1992) 'Update on accelerated rehabilitation after anterior cruciate ligament reconstruction', *Journal of Orthopaedic and Sports Physical Therapy*, 15(6), pp. 303–308. doi: 10.2519/jospt.1992.15.6.303.

Sherman, S. L. *et al.* (2021) 'ACL Study Group presents the global trends in ACL reconstruction: Biennial survey of the ACL Study Group', *Journal of ISAKOS*, 6(6), pp. 322–328. doi: 10.1136/jisakos-2020-000567.

Singh, N. (2018) 'International Epidemiology of Anterior Cruciate Ligament Injuries', *Orthopedic Research Online Journal*, 1(5), pp. 1–4. doi: 10.31031/oproj.2018.01.000525.

"The Anatomy and Biomechanics of the Posterior Cruciate Ligament." *Physio Study*, 3 Mar. 2021, physio-study.com/posterior-cruciate-ligament-anatomy-and-biomechanics/#more-2423. Accessed 8 Feb. 2023.

Thomas, A. C. *et al.* (2013) ‘Lower extremity muscle strength after anterior cruciate ligament injury and reconstruction’, *Journal of Athletic Training*, 48(5), pp. 610–620. doi: 10.4085/1062-6050-48.3.23.

Velázquez-Saornil, J. *et al.* (2017) ‘Efficacy of quadriceps vastus medialis dry needling in a rehabilitation protocol after surgical reconstruction of complete anterior cruciate ligament rupture’, *Medicine (United States)*, 96(17). doi: 10.1097/MD.0000000000006726.

Vidmar, M. F. *et al.* (2020) ‘Isokinetic eccentric training is more effective than constant load eccentric training for quadriceps rehabilitation following anterior cruciate ligament reconstruction: a randomized controlled trial’, *Brazilian Journal of Physical Therapy*, 24(5), pp. 424–432. doi: 10.1016/j.bjpt.2019.07.003.

Wilk, K. E. and Arrigo, C. A. (2016) ‘Preoperative Phase in the Rehabilitation of the Patient Undergoing Anterior Cruciate Ligament Reconstruction’, *Operative Techniques in Sports Medicine*, 24(1), pp. 12–20. doi: 10.1053/j.otsm.2015.10.003.

Wilk, K. E. and Arrigo, C. A. (2017) ‘Rehabilitation Principles of the Anterior Cruciate Ligament Reconstructed Knee: Twelve Steps for Successful Progression and Return to Play’, *Clinics in Sports Medicine*, 36(1), pp. 189–232. doi: 10.1016/j.csm.2016.08.012.

Won, Y. H., Ko, M. H. and Kim, D. H. (2021) ‘Intermittent pneumatic compression for prolonged standing workers with leg edema and pain’, *Medicine*, 100(28), p. e26639. doi: 10.1097/MD.0000000000026639.

Wright, R. W. *et al.* (2008a) ‘A Systematic Review of Anterior Cruciate Ligament Reconstruction Rehabilitation Part I: Continuous Passive Motion, Early Weight Bearing, Postoperative Bracing, and Home-Based Rehabilitation’, *Journal of Knee Surgery*, 21(3), pp. 217–224. doi: 10.1055/s-0030-1247822.

Wright, R. W. *et al.* (2008b) ‘A Systematic Review of Anterior Cruciate Ligament Reconstruction Rehabilitation Part II: Open Versus Closed Kinetic Chain Exercises, Neuromuscular Electrical Stimulation, Accelerated Rehabilitation, and Miscellaneous Topics’, *Journal of Knee Surgery*, 21(3), pp. 225–234. doi: 10.1055/s-0030-1247823.

Wright, R. W. *et al.* (2015) ‘Anterior Cruciate Ligament Reconstruction Rehabilitation: MOON Guidelines’, *Sports Health*, 7(3), pp. 239–243. doi: 10.1177/1941738113517855.

Yabroudi, M. A. and Irrgang, J. J. (2013) ‘Rehabilitation and Return to Play After Anatomic Anterior Cruciate Ligament Reconstruction’, *Clinics in Sports Medicine*, 32(1), pp. 165–175. doi: 10.1016/j.csm.2012.08.016.

Appendix

Appendix A Information Sheet

Information Sheet for Participants

Good day, my name is Colett Robbertse. I am a postgraduate student from the University of the Witwatersrand, completing my master's degree. I am doing a research study on the rehabilitation of ACL repair patients, as part of my studies. I would like to invite you to participate in my study.

Importance of this Study

The aim of the study is to determine the management strategy and treatment modalities currently used by physiotherapists in the rehabilitation of post-operative ACL repair, in Gauteng, South Africa. There is no direct benefit to participate in the study however, the study findings may assist in evidence-based outcomes for rehabilitation of ACL repair patients.

What are you expected to do?

Should you agree to participate in this study, you will be asked to complete a questionnaire.
The questionnaire has three sections/parts: Part 1 - demographic information, Part 2 - information pertaining to the rehabilitation protocol that you use, Part 3 - information pertaining to physiotherapy treatment modalities.
You will receive a link to the questionnaire. It will take approximately 10 minutes of your time to complete the questionnaire. Participation is voluntary and refusal to participate will not have any negative consequences. You may withdraw from the study at any time without fear of suffering any negative repercussions.

What are the risks of taking part in this study?

There are no risks that you will be exposed to, and there is no monetary reward for participating in this study.

Confidentiality

To ensure that confidentiality of participants is maintained, the questionnaire will be completed anonymously. No identifiable information will be requested.

More Information Requests

I am readily available if you have any questions, concerns or if you require more information. You can contact me on 0827774919 or email me at 027027t@students.wits.ac.za. If you have any concerns about the way the study is being conducted, please contact the chairperson of the ethics committee Professor Clement Penny on 0117172301, or via e-mail at Clement.Penny@wits.ac.za. Alternatively, you may contact Zanele Ndlovu on Zanele.Ndlovu@wits.ac.za or Rhulani Mukansi on Rhulani.Mukansi@wits.ac.za or at 0117172700/1234.
If you are willing to participate in this study, please complete the attached forms.

Kind regards and thanks in advance

Colett Robbertse
0827774919
0207027T@students.wits.ac.za

Appendix B Pilot study email to a panel of experts

Good day, my name is Colett Robbertse. I am a postgraduate student from the University of the Witwatersrand, completing my master's degree in Physiotherapy. I am doing a research study on the rehabilitation of patients following an ACL repair. The aim of the study is to determine the management strategy and treatment modalities currently used by physiotherapists in the rehabilitation of patients post-operative ACL repair, in Gauteng, South Africa.

The objectives of the study are:

1. To determine the number of physiotherapists that use an accelerated programme and non- accelerated protocol.
2. To determine the commonly used physiotherapy management strategies and modalities in the first six weeks of post-operative ACL repair rehabilitation.
3. To determine the following rehabilitation goals post ACL repair:
    - If rehabilitation starts preoperatively or postoperatively
    - The WB protocol
    - The frequency of use of protective bracing
    - When patients return to normal function
    - When patients return to sport
4. To determine the outcome measures used in post-operative ACL repair rehabilitation.

There is no direct benefit to participate in the study however, the study findings may assist in evidence-based outcomes for the rehabilitation of patients following an ACL repair**.**

I would like to invite you to participate in my study as part of a panel of experts to validate the content of the questionnaire that will be used in the study. Should you agree to participate in this study, you will be asked to evaluate the self-developed questionnaire attached against the aim and objectives of the study.

The questionnaire has three sections/parts: Part 1 - demographic information, Part 2 - information pertaining to the rehabilitation protocol that you use, Part 3 - information pertaining to physiotherapy treatment modalities.

Furthermore, please let me know the following:

1. Is the content relevant?
2. Are the questions clear?
3. Do the questions capture the topic of ACL rehabilitation effectively?

4. Any suggestions to add to the content of the questionnaire

Your assistance will be greatly appreciated.

Thank you

Colett Robbertse

0827774919

Appendix B Ethical Clearance Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research and Innovation)

TO: Ms C Robbertse
School of Therapeutic Sciences
Department of Physiotherapy
Medical School
University

E-mail: colethrobbertse@gmail.com

CC: Supervisor: Ms V Naidoo
Vaneshveri.Naidoo@wits.ac.za
and <HREC-Medical Research Office@wits.ac.za>

FROM: Mr Iain Burns
Human Research Ethics Committee (Medical)
Tel: 011 717 1252

E-mail: Iain.Burns@wits.ac.za

DATE: 2021/08/23

REF: R14/49

PROTOCOL NO: **M210620** (This is your ethics application reference number. Please quote it in all enquiries, oral or written, relating to this study.)

PROJECT TITLE: *Physiotherapy management of post-operative ACL rehabilitation: a cross-sectional survey in Gauteng, South Africa*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to Government funding of the University.

MSWorks2000/Iain2007/Clearscan.wps

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

2022/04/14

Ms C Robbertse
School of Therapeutic Sciences
Department of Physiotherapy
Medical School
University

Sent by e-mail to: colettrobbertse@gmail.com

Dear Ms Robbertse

Re: **Protocol Ref No:** M210620
Protocol Title: *Physiotherapy management of post-operative ACL rehabilitation: a cross-sectional survey in Gauteng, South Africa*
Principal Investigators: Ms C Robbertse

Thank you for your letter of 2022/04/11.

I confirm that we have noted and approve of your proposal to recruit additional participants by advertising on social media.

I note that by implication and from your questionnaire that you now seem to be looking countrywide for participants. We have no issue with this, but you may have to get Faculty approval to modify your study title, which specifically limits you to Gauteng. If your supervisor agrees with me, the person to approach would be Sandra.Benn@wits.ac.za

In the event of a change of a Faculty-approved study title, please scan me Ms Benn's standard letter and I can modify your clearance certificate.

Thank you for keeping us informed.

Yours Sincerely

.....
Mr I Burns
For the Human Research Ethics Committee (Medical)

.....
Dr CB Penny, Chairperson, Human Research Ethics Committee (Medical)

Appendix C Questionnaire

Physiotherapy management of post-operative ACL Rehabilitation: a cross-sectional survey

Please complete the survey below.

Thank you!

Dear Colleague

Good day, my name is Colett Robbertse. I am a Masters student from the University of the Witwatersrand. I am doing a research study on the rehabilitation of ACL repair patients, as part of my studies. I would like to invite you to participate in my study.

The aim of the study is to determine the management strategy and treatment modalities currently used by physiotherapists in the rehabilitation of post-operative ACL repair, in Gauteng, South Africa. There is no direct benefit to participate in the study however, the study findings will assist in evidence-based outcomes for rehabilitation of patients following ACL repair.

What are you, the participant, expected to do?
Should you agree to participate in this study, you will be asked to complete a questionnaire.

The questionnaire has three sections/parts: part1 demographic information: part2 information pertaining to rehabilitation protocol you use and part3: information pertaining to physiotherapy modalities.

It will take approximately 10 minutes of your time to complete the questionnaires. Participation is voluntary and refusal to participate will not have any negative consequences. You may withdraw from the study at any time without fear of suffering any negative repercussions.

What are the risks of taking part in this study?
There are no risks that you will be exposed to. There is no monetary reward for participating in this study.

Confidentiality
To ensure the confidentiality of participants is maintained, study the questionnaire will be completed anonymously.

More Information Requests
I am readily available if you have any questions, concerns or require more information. Alternatively, you can contact me on 0827774919 or email me at 0207027t@students.wits.ac.za

If you have any concern over the way the study is being conducted, please contact the Chairperson of this Committee who is Professor Clement Penny, who may be contacted on telephone number 011 717 2301, or by e-mail on Clement.Penny@wits.ac.za. The telephone numbers for the Committee secretariat are 011 717 2700/1234 and the e-mail addresses are Zanele.Ndlovu@wits.ac.za and Rhulani.Mukansi@wits.ac.za

If you are willing to participate in this, please complete the following survey. Participation in this survey will be automatically seen as permission and consent given by yourself.

Part 1: Demographic Information

This part of the questionnaire seeks to obtain information regarding specific demographic information about the treating physiotherapist

1 Do you treat patients following an anterior cruciate ligament (ACL) repair?
- ○ Yes
- ○ No

2	Where do you practice physiotherapy?	○ Eastern Cape ○ Free State ○ Gauteng ○ KwaZulu-Natal ○ Limpopo ○ Mpumalanga ○ Northern Cape ○ North West
3	What is your age?	_____
4	How many years have you been practising as a physiotherapist?	_____
5	How many years have you been managing patients post ACL repair?	_____
6	Which post graduate courses have you competed?	☐ OMT1 ☐ SPT ☐ Master in OMT ☐ Master in SPT ☐ PhD ☐ ACL rehabilitation courses ☐ Other ☐ None
	Please give detail about the ACL rehabilitation courses	_____
	If 'other' is selected above, please elaborate	_____

Part 2: Protocol

This part of the questionnaire seeks to obtain information regarding specific protocols used in post-operative ACL rehabilitation patients.

The questions pertain specifically to the rehabilitation of post operative ACL injury without other complicating factors like meniscus and other ligament injury involvement.

Accelerated protocol is defined as the concept of gaining terminal knee extension immediately following reconstruction, early progressive range of motion and early progressive weight bearing

Non- accelerated protocol is defined as knee immobilisation for the first 2 weeks, non weight bearing mobilisation with progression to full weight bearing after 6 weeks post operatively. Progressive ROM only after the stability of the ACL graft is determined.

Return to normal function in the context of this questionnaire is that the patient has obtained pre-injury level of function in activities of daily living.

Return to sport in the context of this questionnaire is that the athlete has returned to his or her sport and is performing at or better than pre-injury level.

What protocol do you use for rehabilitation of patients that had a ACL repair?	○ Accelerated ○ Non-accelerated ○ Other
if 'other' is selected above, please elaborate	_____
When does rehabilitation start?	○ Pre-Operative ○ Post-Operative
What weight bearing restriction do you have for post-operative ACL patients from 0-6 Weeks?	○ Full Weight as Soon as Pain Allows ○ Partial weight bearing ○ Non Weight bearing ○ Other
if 'other' is selected above, please elaborate	_____
How long do your patients use a range of motion (ROM) brace postoperatively?	○ No ROM brace ○ 0-2 Weeks ○ 2-4 Weeks ○ 4-6 Weeks ○ 6-12 Weeks ○ Other
if 'other' is selected above, please elaborate	_____

5	What protocol do you use for ROM progression?	○ Immediate progression with knee ROM ○ Set ROM progression according the guidelines provided by the attending orthopaedic surgeon ○ Other
	If 'other' is selected above, please elaborate	_____
6	When do your patients return to normal function?	○ 0-6 Weeks ○ 6-12 Weeks ○ 12-18 Weeks ○ Determined by functional test ○ Other
	If 'Determined by functional test' please indicate what functional test you use	_____
	If 'other' is selected above, please elaborate	_____
7	When do your patients return to sport?	○ 0-6 Months ○ 6-9 Months ○ 9-12 Months ○ Return to sport is determined by functional test ○ Other
	If 'Determined by functional test' please indicate what functional test you use	_____
	If 'other' is selected above, please elaborate	_____

Part 3: Exercise Program

This part of the questionnaire seeks to obtain information regarding specific exercise protocols used in post-operative ACL rehabilitation patients.

1 Which physiotherapy interventions do you use to treat patients post ACL repair?

- ○ Home Based Program With Exercises
- ○ Weekly Physiotherapy Treatment and Home Exercises
- ○ Bi Weekly Physiotherapy Treatment And Home Exercises
- ○ Other

If 'other' is selected above, please elaborate

_____

2 Which modalities do you use when treating patients post ACL repair?

- ☐ Continuous passive motion (CPM)
- ☐ Neuromuscular Stimulation
- ☐ Cryotherapy
- ☐ Dry Needling
- ☐ Blood Flow Restriction
- ☐ Massage
- ☐ Myofascial release
- ☐ Peripheral manual therapy
- ☐ Laser
- ☐ Ultrasound
- ☐ Other

If 'other' is selected above, please elaborate

_____

3 Which outcome measures do you use when assessing patients post ACL repair?

- ☐ Visual Analogue Scale (VAS)
- ☐ Numeric Pain Scale (NPS)
- ☐ Anterior Drawer Test
- ☐ Self Reported Physical Function
- ☐ Knee Injury and Osteoarthritis Outcome Score
- ☐ Range of Motion
- ☐ Other

If 'other' is selected above, please state which outcome measures you use.

_____

When do you begin the following exercises?

		0-1 week	1-2 weeks	2-3 weeks	3-4 weeks	4-5 weeks	6+ weeks
4	Isometric	○	○	○	○	○	○
5	Eccentric	○	○	○	○	○	○
6	Concentric	○	○	○	○	○	○
7	Cross Training	○	○	○	○	○	○
8	Open Chain	○	○	○	○	○	○
9	Close Chain	○	○	○	○	○	○
10	Terminal Locking	○	○	○	○	○	○
11	Full Extension	○	○	○	○	○	○

Appendix D Turnitin Report

0207027t research report

ORIGINALITY REPORT

11%	8%	6%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Sports Injuries, 2015. Publication	1%
2	core.ac.uk Internet Source	<1%
3	wiredspace.wits.ac.za Internet Source	<1%
4	usir.salford.ac.uk Internet Source	<1%
5	Submitted to AUT University Student Paper	<1%
6	link.springer.com Internet Source	<1%
7	www.science.gov Internet Source	<1%
8	dokumen.pub Internet Source	<1%
9	hdl.handle.net Internet Source	<1%

10	openrepository.aut.ac.nz Internet Source	<1 %
11	"Rotatory Knee Instability", Springer Science and Business Media LLC, 2017 Publication	<1 %
12	Joachim Van Cant, Benoît Pairot de Fontenay, Charbel Douaihy, Alexandre Rambaud. "Characteristics of return to running programs following an anterior cruciate ligament reconstruction: A scoping review of 64 studies with clinical perspectives", Physical Therapy in Sport, 2022 Publication	<1 %
13	docplayer.net Internet Source	<1 %
14	bjsm.bmj.com Internet Source	<1 %
15	eresearch.qmu.ac.uk Internet Source	<1 %
16	Submitted to Kaplan International Colleges Student Paper	<1 %
17	www.westernschools.com Internet Source	<1 %
18	theses.ucalgary.ca Internet Source	<1 %

19	worldwidescience.org Internet Source	<1 %
20	www.researchbank.ac.nz Internet Source	<1 %
21	www.sciencedirect.com Internet Source	<1 %
22	Submitted to Austin Peay State Uniersity Student Paper	<1 %
23	www.tucantravel.com Internet Source	<1 %
24	www.i-scholar.in Internet Source	<1 %
25	"Controversies in the Technical Aspects of ACL Reconstruction", Springer Science and Business Media LLC, 2017 Publication	<1 %
26	Parry, Gemma. "The Reliability and Validity Development of an MSK Profiling Tool and Its Value in Youth Athletes and Prospective Injury Risk", University of Salford (United Kingdom), 2022 Publication	<1 %
27	Submitted to University of Gloucestershire Student Paper	<1 %

28	Submitted to University of St Mark and St John Student Paper	<1 %
29	utpjournals.press Internet Source	<1 %
30	www.aaos.org Internet Source	<1 %
31	www.tandfonline.com Internet Source	<1 %
32	Polly de Mille, Jamie Osmak. "Performance: Bridging the Gap After ACL Surgery", Current Reviews in Musculoskeletal Medicine, 2017 Publication	<1 %
33	e-space.mmu.ac.uk Internet Source	<1 %
34	open.uct.ac.za Internet Source	<1 %
35	"The Future of Orthopaedic Sports Medicine", Springer Science and Business Media LLC, 2020 Publication	<1 %
36	www.physio-pedia.com Internet Source	<1 %
37	dc.uwm.edu Internet Source	<1 %

38	pure.southwales.ac.uk Internet Source	<1 %
39	repository.up.ac.za Internet Source	<1 %
40	www.researchgate.net Internet Source	<1 %
41	David Figueroa, Guillermo Arce, M. Joao Espregueira, Rodrigo Maestu et al. "Return to Sport Soccer after Anterior Cruciate Ligament Reconstruction: ISAKOS Consensus", Journal of ISAKOS, 2022 Publication	<1 %
42	Submitted to Oklahoma State University Student Paper	<1 %
43	journals.lww.com Internet Source	<1 %
44	Jorge Velázquez-Saornil, Beatriz Ruíz-Ruíz, David Rodríguez-Sanz, Carlos Romero-Morales et al. "Efficacy of quadriceps vastus medialis dry needling in a rehabilitation protocol after surgical reconstruction of complete anterior cruciate ligament rupture", Medicine, 2017 Publication	<1 %
45	Submitted to University of Salford Student Paper	<1 %

46	docksci.com Internet Source	<1 %
47	pure.rug.nl Internet Source	<1 %
48	rdw.rowan.edu Internet Source	<1 %
49	Submitted to Edith Cowan University Student Paper	<1 %
50	S. Ferree, V. Neuhaus, C. S. Mudgal. "Isolated tenosynovitis of the extensor carpi radialis brevis and longus tendons in the second dorsal compartment of the wrist", Journal of Hand Surgery (European Volume), 2012 Publication	<1 %
51	www.ncbi.nlm.nih.gov Internet Source	<1 %
52	M. Marieswaran, Ishita Jain, Bhavuk Garg, Vijay Sharma, Dinesh Kalyanasundaram. "A Review on Biomechanics of Anterior Cruciate Ligament and Materials for Reconstruction", Applied Bionics and Biomechanics, 2018 Publication	<1 %
53	Peta T. Johnston, Julian A. Feller, Jodie A. McClelland, Kate E. Webster. "Knee strength deficits following anterior cruciate ligament reconstruction differ between quadriceps and	<1 %

	hamstring tendon autografts", Knee Surgery, Sports Traumatology, Arthroscopy, 2021 Publication	
54	Submitted to University of Cumbria Student Paper	<1 %
55	Submitted to University of KwaZulu-Natal Student Paper	<1 %
56	Yuta Koshino, Shohei Taniguchi, Takumi Kobayashi, Mina Samukawa, Masayuki Inoue. "Protocols of rehabilitation and return to sport, and clinical outcomes after medial patellofemoral ligament reconstruction with and without tibial tuberosity osteotomy: a systematic review", International Orthopaedics, 2022 Publication	<1 %
57	journals.plos.org Internet Source	<1 %
58	"Posters", Knee Surgery, Sports Traumatology, Arthroscopy, 2008 Publication	<1 %
59	Submitted to Glasgow Caledonian University Student Paper	<1 %
60	Kevin E. Wilk, Leonard C. Macrina, E. Lyle Cain, Jeffrey R. Dugas, James R. Andrews. "Recent Advances in the Rehabilitation of Anterior	<1 %

	Cruciate Ligament Injuries", Journal of Orthopaedic & Sports Physical Therapy, 2012 Publication	
61	Submitted to University of Iceland Student Paper	<1 %
62	Submitted to University of Northampton Student Paper	<1 %
63	Submitted to University of Utah Student Paper	<1 %
64	Vasileios Korakakis, Argyro Kotsifaki, Alexandra Korakaki, Stefanos Karanasios, Rodney Whiteley. "Current perspectives and clinical practice of physiotherapists on assessment, rehabilitation, and return to sport criteria after anterior cruciate ligament injury and reconstruction. An online survey of 538 physiotherapists", Physical Therapy in Sport, 2021 Publication	<1 %
65	Walters, Vanessa. "The Biomechanical Changes During Sportspecific Tasks and Different Commercially Available Footwear in Individuals Following Meniscectomy", University of Salford (United Kingdom) Publication	<1 %
66	etd.uwc.ac.za Internet Source	<1 %

67	Kaycee E. Glattke, Sailesh V. Tummala, Boaz Goldberg, Heather Menzer, Anikar Chhabra. "There is Substantial Variation in Rehabilitation Protocols Following Anterior Cruciate Ligament Reconstruction: A Survey of 46 American Orthopedic Surgeons", Arthroscopy: The Journal of Arthroscopic & Related Surgery, 2022 Publication	<1 %
68	www.eoc.org.hk Internet Source	<1 %
69	Birchmeier, Thomas Brian. "Change of Direction and Psychological Response to Injury as Risk Factors for Second Acl Injury", Michigan State University, 2021 Publication	<1 %
70	jeo-esska.springeropen.com Internet Source	<1 %
71	www.ejurnal.poltekkesjakarta3.ac.id Internet Source	<1 %
72	www.healio.com Internet Source	<1 %
73	www.ijirms.in Internet Source	<1 %
74	www.iscsjournal.com Internet Source	<1 %

75	Åsa Revenäs, Annchristin Johansson, Jerzy Leppert. "A randomized study of two physiotherapeutic approaches after knee ligament reconstruction", Advances in Physiotherapy, 2009 Publication	<1 %
76	Hughton, Anna. "Pelvic floor muscle exercise protocols for post-prostatectomy urinary incontinence: A survey of physiotherapists current practice in Canada", Proquest, 20111003 Publication	<1 %
77	Håvard Moksnes, Clare L. Ardern, Joanna Kvist, Lars Engebretsen, May Arna Risberg, Grethe Myklebust, Hege Grindem. "Assessing implementation, limited efficacy, and acceptability of the BEAST tool: A rehabilitation and return-to-sport decision tool for nonprofessional athletes with anterior cruciate ligament reconstruction", Physical Therapy in Sport, 2021 Publication	<1 %
78	Submitted to Institute of Technology Carlow Student Paper	<1 %
79	Ishraq Joarder, Seika Taniguchi, Mary Elizabeth Snow, Andrea Mendoza. "Defining “successful” treatment outcomes in	<1 %

	adolescent idiopathic scoliosis: a scoping review", Research Square Platform LLC, 2022 Publication	
80	Jamie Cunha, Daniel J. Solomon. "ACL Prehabilitation Improves Postoperative Strength and Motion and Return to Sport in Athletes", Arthroscopy, Sports Medicine, and Rehabilitation, 2022 Publication	<1 %
81	Sharir, Raihana. "A Critical Evaluation of Biomechanical Risk Factors for ACL Injuries during Dynamic Activities.", Liverpool John Moores University (United Kingdom), 2021 Publication	<1 %
82	Wright Watson, Roxanne Keisha. "Black Women in STEM: Factors Influencing Black Females to Enter and Succeed in Science, Technology, Engineering, and Mathematics in Higher Education", Capitol Technology University, 2021 Publication	<1 %
83	ar.scribd.com Internet Source	<1 %
84	crazyfordogs.com Internet Source	<1 %
85	danthephysio.com Internet Source	<1 %

86	dspace.muhas.ac.tz:8080 Internet Source	<1 %
87	formative.jmir.org Internet Source	<1 %
88	gupea.ub.gu.se Internet Source	<1 %
89	josr-online.biomedcentral.com Internet Source	<1 %
90	orthopt.org Internet Source	<1 %
91	www.espiongroup.com Internet Source	<1 %
92	www.grandroundsnow.com Internet Source	<1 %
93	www.jospt.org Internet Source	<1 %
94	www.uhcw.nhs.uk Internet Source	<1 %
95	Agostinho Mussa, Wolfgang Kalkreuth, Ana Maria Pimentel Mizusaki, Marleny Blanco González et al. "Evaluation of the hydrocarbon generation potential of the Pimenteiras Formation, Parnaiba Basin (Brazil) based on total organic carbon content and	<1 %

Rock-Eval pyrolysis data", Energy Exploration & Exploitation, 2020
Publication

96	Cristina Bobes Álvarez, Paloma Issa-Khozouz Santamaría, Rubén Fernández-Matías, Daniel Pecos-Martín et al. "Comparison of Blood Flow Restriction Training versus Non-Occlusive Training in Patients with Anterior Cruciate Ligament Reconstruction or Knee Osteoarthritis: A Systematic Review", Journal of Clinical Medicine, 2020 Publication	<1 %
97	Hoeft, Rachel. "Confidence Issues during Athletic Injury Recovery: A Systematic Literature Review", University of Arizona Global Campus, 2021 Publication	<1 %
98	Ibarra, Luis Jesus Sedano. "The Efficacy of Whole-Body Vibration and Balance Training on Dynamic Balance and Eversion Strength in Active Adults with Chronic Ankle Instability: A Meta-Analysis", California State University, Fresno Publication	<1 %
99	Johnston, Christoher David. "Quadriceps Muscle Quality Following Anterior Cruciate Ligament Reconstruction: A Potential Mechanism for Quadriceps Dysfunction and	<1 %

Post-Traumatic Knee Osteoarthritis.", The University of North Carolina at Chapel Hill, 2020
Publication

---

100 Luca Macchiarola, Nicola Pizza, Vittorio Patania, Alberto Grassi, Giacomo Dal Fabbro, Maurilio Marcacci, Stefano Zaffagnini. "Double-bundle non-anatomic ACL revision reconstruction with allograft resulted in a low revision rate at 10 years", Knee Surgery, Sports Traumatology, Arthroscopy, 2022 <1 %
Publication

---

101 P. Bordes, E. Laboute, A. Bertolotti, J.F. Dalmay, P. Puig, P. Trouve, E. Verhaegue, P.A. Joseph, P. Dehail, M. De Seze. "No beneficial effect of bracing after anterior cruciate ligament reconstruction in a cohort of 969 athletes followed in rehabilitation", Annals of Physical and Rehabilitation Medicine, 2017 <1 %
Publication

---

102 Riccardo Cristiani, Christina Mikkelsen, Peter Wange, Daniel Olsson, Anders Stålman, Björn Engström. "Autograft type affects muscle strength and hop performance after ACL reconstruction. A randomised controlled trial comparing patellar tendon and hamstring tendon autografts with standard or <1 %

	accelerated rehabilitation", Knee Surgery, Sports Traumatology, Arthroscopy, 2020 Publication	
103	Stinecipher, Hailey. "Differences in Single-Limb Stability during Dynamic Tasks in Individuals with Chronic Ankle Instability and ACL Injuries", California State University, Fresno Publication	<1 %
104	Yao Zhu, Shuying Luo, Hanqing He, Rui Yan, Yang Zhou, Xuan Deng, Xuewen Tang. "Non-Prescription Antibiotic Use for Cough Among Chinese Children Aged Under 5 Years: A Community-Based Cross-Sectional Study", Research Square, 2020 Publication	<1 %
105	agile.csp.org.uk Internet Source	<1 %
106	archive.org Internet Source	<1 %
107	cdle.colorado.gov Internet Source	<1 %
108	crimsonpublishers.com Internet Source	<1 %
109	d-scholarship.pitt.edu Internet Source	<1 %

110	digitalcommons.pepperdine.edu Internet Source	<1 %
111	en.wikipedia.org Internet Source	<1 %
112	epdf.tips Internet Source	<1 %
113	eprints.glos.ac.uk Internet Source	<1 %
114	eprints.whiterose.ac.uk Internet Source	<1 %
115	espace.library.uq.edu.au Internet Source	<1 %
116	etheses.whiterose.ac.uk Internet Source	<1 %
117	fmcmpd.org Internet Source	<1 %
118	ijspt.org Internet Source	<1 %
119	onlinelibrary.wiley.com Internet Source	<1 %
120	publikationen.uni-tuebingen.de Internet Source	<1 %
121	pure.tue.nl Internet Source	<1 %

122	repositorio.ufmg.br Internet Source	<1 %
123	research.tees.ac.uk Internet Source	<1 %
124	scholar.sun.ac.za Internet Source	<1 %
125	scholars.direct Internet Source	<1 %
126	slideheaven.com Internet Source	<1 %
127	sportsmedicine-open.springeropen.com Internet Source	<1 %
128	uarkive.uark.edu Internet Source	<1 %
129	www.rbf-bjpt.org.br Internet Source	<1 %
130	www.semanticscholar.org Internet Source	<1 %
131	www.springermedizin.de Internet Source	<1 %
132	"Return to Play in Football", Springer Science and Business Media LLC, 2018 Publication	<1 %

133	Anita M. Rivera - Brown, Walter R. Frontera, Richard Fontanez, William F. Micheo. " Evidence for Isokinetic and Functional Testing in Return to Sport Decisions Following Surgery ", PM&R, 2022 Publication	<1 %
134	Daniel Caetano, Catarina Oliveira, Cristiana Correia, Pedro Barbosa, António Montes, Paulo Carvalho. "Rehabilitation outcomes and parameters of Blood Flow Restriction Training in ACL injury: a scoping review", Physical Therapy in Sport, 2021 Publication	<1 %
135	Michael A. Hunt, Stephen R. Di Ciacca, Ian C. Jones, Beverley Padfield, Trevor B. Birmingham. "Effect of Anterior Tibiofemoral Glides on Knee Extension during Gait in Patients with Decreased Range of Motion after Anterior Cruciate Ligament Reconstruction", Physiotherapy Canada, 2010 Publication	<1 %
136	Wayne A. Fausett, Duncan A. Reid, Peter J. Larmer. "Current perspectives of New Zealand physiotherapists on rehabilitation and return to sport following anterior cruciate ligament reconstruction: A survey", Physical Therapy in Sport, 2021 Publication	<1 %

137	www.elitehktutors.com Internet Source	<1 %
138	"ACL Injuries in the Female Athlete", Springer Science and Business Media LLC, 2018 Publication	<1 %
139	"Injuries and Health Problems in Football", Springer Science and Business Media LLC, 2017 Publication	<1 %
140	Jody McGowan, Duncan A. Reid, Jill Caldwell. "Post-operative rehabilitation of anterior cruciate ligament reconstruction in the skeletally immature child: a systematic review of the literature", Physical Therapy Reviews, 2017 Publication	<1 %
141	Michelle E. Arakgi, Timothy A. Burkhart, Takashi Hoshino, Ryan Degen, Alan Getgood. "Biomechanical Comparison of Three Suspensory Techniques for all Soft Tissue Central Quadriceps Tendon Graft Fixation", Arthroscopy, Sports Medicine, and Rehabilitation, 2022 Publication	<1 %
142	Renato Andrade, Rogério Pereira, Robert van Cingel, J Bart Staal, João Espregueira-Mendes. "How should clinicians rehabilitate patients	<1 %

	after ACL reconstruction? A systematic review of clinical practice guidelines (CPGs) with a focus on quality appraisal (AGREE II)", British Journal of Sports Medicine, 2020 Publication	
143	Rob P A Janssen, Nicky van Melick, Jan B A van Mourik, Max Reijman, Lodewijk W van Rhijn. "ACL reconstruction with hamstring tendon autograft and accelerated brace-free rehabilitation: a systematic review of clinical outcomes", BMJ Open Sport & Exercise Medicine, 2018 Publication	<1 %
144	Robey, Nathan John. "The Effect of Visual Disruption on Stability After Anterior Cruciate Ligament Reconstruction.", University of Northern Colorado, 2021 Publication	<1 %
145	The Knee Joint, 2012. Publication	<1 %
146	Yu Hui Won, Myoung-Hwan Ko, Dong Hyun Kim. "Intermittent pneumatic compression for prolonged standing workers with leg edema and pain", Medicine, 2021 Publication	<1 %
147	spark.bethel.edu Internet Source	<1 %