

# **Review of the most used strength exercises in rehabilitation after anterior cruciate ligament injury in athletes**

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## Abstract

The purpose of this review was to evaluate which strength exercises are most used in rehabilitation of an anterior cruciate ligament injured knee in athletes. There are different surgical and rehabilitative procedures, and there is disagreement regarding which type of exercises are the most effective ones in letting the athlete recover and regain normal function when completed. This review used papers found in the literature to answer the research question: *Which strength exercises are effective on regaining normal knee function after anterior cruciate ligament knee injury in athletes?* The literature found in PubMed and PEDro showed papers that included five exercises that were used the most, and these were squats, leg extension, knee flexion, leg press and step ups/step downs. This review points out that these exercises are effective in rehabilitating from anterior cruciate ligament injury, but that there are several other factors to take into consideration. One such factor is that other types of exercises are used in combination with strength exercises, and that this combination may be crucial for recovery.

Keywords: Anterior cruciate ligament, injury, rehabilitation, athletes, recovery, knee function, surgery.

Formålet med denne oversiktsstudien var å evaluere hvilke styrkeøvelser som brukes oftest i rehabilitering etter anterior cruciate ligament-skade i kneet hos atleter. Det finnes ulike operasjons- og rehabiliteringsprosedyrer, og det finnes enda ingen universell standard som sier hvilke treningsøvelser som er mest effektive, og som lar atleten gjenopprette normal funksjon i kneet etter endt rehabiliteringsperiode. Denne oversiktsstudien brukte artikler funnet i litteraturen for å besvare følgende problemstilling: *Hvilke styrkeøvelser er effektive for å gjenvinne normal knefunksjon etter anterior cruciate ligament-kneskade hos atleter?* Litteraturen funnet på PubMed og PEDro inneholdt artikler som inkluderte fem øvelser som ble brukt mest. Disse var knebøy, kneekstensjon, knefleksjon, beinpress og step ups/step downs. Denne studien peker mot at disse øvelsene er effektive for å rehabilitere pasienter etter denne skaden, men at det finnes flere faktorer som også må tas hensyn til i en slik prosess. Én slik faktor er at det vanligvis brukes andre treningsmetoder i kombinasjon med styrketrening for å oppnå normal funksjon, og at dette kan være helt essensielt for atletens bedring.

Nøkkelord: Anterior cruciate ligament, skade, rehabilitering, atleter, knefunksjon, rekonstruksjon.

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## 1.0 INTRODUCTION

The anterior cruciate ligament (ACL) is a ligament in the anterior part of the human knee. This ligament is responsible for stability of the knee. ACL injuries are common in athletes because in sports, the knee is often exposed to vigorous changes in movement which can lead to sprain or tearing of the ligament. ACL injuries can occur in several ways, but almost 80% are caused by non-contact mechanisms, such as landing from a jump, sudden change in direction or decelerating (American Orthopaedic Society for Sports Medicine, 2007). An ACL injury can cause functional and static instability that leads to changes in motion patterns, and is in many cases treated with surgical operation, and rehabilitation. The motive for rehabilitation is to regain a functional stability and reduce the risk of re-injury (Kvist, 2004). If surgery proves necessary, rehabilitation should start prior to this. If the patient doesn't carry out preoperative rehabilitation, the risk of arthrofibrosis may increase, which can lead to loss of movement (Wilk & Arrigo, 2016). There are different ways to rehabilitate athletes with this injury, and this review will try to evaluate which strength exercises result in the most effective recovery from ACL injury. Such exercises are likely to include muscles that surround the knee, and that protect it by stabilizing and strengthening it. Exercises may be open kinetic chain (OKC) or closed kinetic chain (CKC) exercises. "Open kinetic chain exercises are typically non-weight bearing, with movement occurring at a single joint. The distal segment is free to move, and the resistance is usually applied to the distal segment. An example would be a knee extension exercise [...]. Closed kinetic chain exercises are typically weight bearing. Movement at several joints is required to complete the movement, the distal segment is usually fixed to a supporting surface, and the resistance may be applied both proximally and distally. An example of a CKC exercise would be a squat" (Fitzgerald, 1997, p. 1748). This review also includes return to sport rates, because when an athlete is able to return to the previous level of sport it can indicate that the rehabilitation has been successful.

Most of the literature available today includes balance, plyometric, neuromuscular and strengthening training, or others, and these are usually combined in various ways to reach the individual rehabilitation goals. In this review the emphasis will be put on strength training and exercises because there are very few articles on this specific topic. The aim is to provide an overview of the most commonly used strength exercises in rehabilitation from ACL injury, and this review will try to provide such an overview by answering the following question:

*Which strength exercises are effective on regaining normal knee function after anterior cruciate ligament knee injury in athletes?*

The background for this aim is that this information may be used by clinicians who are responsible for rehabilitation, and that these exercises should be included to provide an effective rehabilitation. It may also be viewed as a “guideline” to others who wish to strengthen the muscles surrounding the knee joint, and may function as a preventative training method to avoid ACL injury.

## **2.0 METHODS**

In this review the databases PEDro and PubMed were used. When searching in PEDro the search term “ACL rehabilitation” was used and the following options were selected: strength training, lower leg or knee, sports, clinical trial and articles published since 1980. The results showed 55 articles. In PubMed the search terms “ACL injury”, “rehabilitation”, “athletes”, “strength” and “reconstruction” were used and it showed 48 articles. Options selected were: published from 1980 until today, clinical trial and humans. This resulted in 103 articles combined. Criteria for exclusion in the review were 1) when the patients were non-athletes, 2) when the subjects were cadavers and 3) when the strength exercises used were not presented. The reference lists were reviewed and four papers were in addition included, resulting in seven papers for this review. The literature search was done from March 7th until April 8th.

## **3.0 RESULTS**

*Which strength exercises are effective on regaining normal knee function after anterior cruciate ligament knee injury in athletes?* From the literature search this review finds that exercises that involve the lower extremity are important, including the quadriceps and hamstring, as well as others (MacDonald, Hedden, Pacin & Huebert, 1995, Eitzen, Moksnes, Snyder-Mackler & Risberg, 2011). Exercises often used are squats, leg extension, knee flexion, leg press and step ups/step downs. These are included in the articles presented below, where some may use all of them while others use a few combined with other exercises or training methods. Table 1 presents an overview of the papers included in this review.

**Table 1.** An overview of the papers included in this review. Including authors and year of publication, duration of rehabilitation (in weeks), number of patients, exercises used, and the return to sport rate.

Authors (year)	Duration	N	Squat	Leg ex.	Knee flex.	Leg press	Step up/down	RTS (%)
Shelbourne & Nitz (1990) <sup>a</sup>	48	138	X	X	X		X	95
		247	X	X		X	X	98
Marder, Raskind & Carroll (1991)	12	72		X	X			64
Draper & Ladd (1993)	32	58	X	X	X	X	X	74
MacDonald, Hedden, Pacin, & Huebert (1995)	24	40	X	X	X	X		86
Nakayama, Shirai, Narita, Mori & Kobayashi (2000)	20	50	X					92
Hartigan, Axe & Snyder-Mackler (2010)	12	40		X		X		78
							X	
Eitzen, Moksnes, Snyder-Mackler & Risberg (2011)	5	100	X	X	X	X	X	96 <sup>b</sup>

*N* = number of patients. *RTS* = return to sports. <sup>a</sup>= Patients were divided into two different groups (accelerated and non-accelerated) and *RTS* was not objective but subjective measures. <sup>b</sup> = *RTS* not given, interpreted as those without complications (96%) were able to *RTS*.

Shelbourne and Nitz (1990) had an initial rehabilitation program that they used for one year. They discovered that patients who progressed as desired and had a protocol directed more subjectively, could return to sports earlier. These patients were permitted to do earlier weight bearing. They then started an accelerated program two years later with new patients. They used a comparative study with subjective and objective testing to compare the two programs. They found that the accelerated program had several advantages where the patients gained complete knee motion and leg strength in less time. In the accelerated program the patient would do full leg extension the first day after surgery, and closed kinetic exercises were emphasized while open kinetic exercises were avoided. Alternative exercises were provided if the patient was unable to execute the intentional exercises and the patients would also not use crutches or other equipments, if possible, in the accelerated program. In the end, a questionnaire was made for evaluation of self-rated stability in both groups. The patients were to answer the self-rated stability on a scale where 20 was the best score. 95% of the patients in the non-accelerated program answered 20 of 20, and 98% of the the patients in the accelerated program answered 20 of 20.

Marder, Raskind and Carroll (1991) looked at patients who underwent ACL reconstruction with either autogenous patellar tendon or combined semitendinosus, or gracilis tendons. They compared these methods and found that there was no significant difference. A rehabilitation regime was used on patients who had chronic laxity due to the injury. 24% of the patients reported knee pain under the follow up when doing activity. They said that their rehabilitation method using mostly passive extension and active flexion was satisfactory, but they did postpone weight bearing until six weeks post operation. This was because the patients used patellar tendon graft, and using weight bearing was not advisable in their condition. They believed that they would get fewer reports on pain if they had performed isokinetic training at slow speeds during the rehabilitation program, and they also suspected that not all patients were motivated to achieve maximal rehabilitation.

Draper and Ladd (1993) initiated a moderately accelerated protocol and looked at long-term effects on incorporating closed kinetic chain exercises, weight bearing and immediating full motion early in the rehabilitation. In addition, they looked at early return to sports. They also wanted to look at the patients activity levels one to two years after the procedure. 69% of the patients reported “good to excellent” function in the knee after rehabilitation. They also used bicycling and running in a pool, but almost exclusively strengthening exercises were used in the rehabilitation program. They mention that reports regarding accelerated programs should also include evaluation of measures such as pain, mechanical abnormalities (locking of knee) and perception of stability. The biggest focus of many rehabilitation programs are objective measures and tests such as isokinetic measures, measures on ligament stability and range of motion. They say that even though these objective measures showed good results, they were interested in the subjective assessments of their knee function. Objective measures might show that the patient is ready for early return to sports, but for the most successful return, the patient must also feel confident about the function of the injured knee. They report that most of their patients returned to sports and some even increased their level.

In one study (MacDonald, Hedden, Pacin & Huebert, 1995) patients were treated with an accelerated rehabilitation approach including 12 passive (collision) and 28 active (non-collision) injuries. Most injuries occurred during sports such as hockey and basketball. Before surgery all patients had at least 90° arc of motion, with 29 of them demonstrating a full range of motion (ROM). The patients used a Generation II rehabilitation brace after surgery, and



started a program for active knee ROM during the first two weeks. Hip and ankle maintenance exercises were also included. They were taught isometric quadricep exercises to do at home for two weeks which should lead to the achievement of at least 90° flexion. Strength training started actively in week four. Patients participating in non-pivoting sports were allowed to return to sports after four months with full ROM and 85% quadricep strength as criterions. Return to pivoting sports began after six months. They found that 95% of the participants had a full ROM at the end of the follow-up that ranged between 20-33 months. 92% (of a total of 37 patients with adequate follow-up data) had good or excellent results. They also experienced no pain, swelling, locking or giving away (MacDonald, Hedden, Pacin & Huebert, 1995).

Nakayama, Shirai, Narita, Mori and Kobayashi (2000) investigated knee function and rehabilitated competitive athletes after ACL reconstruction. All patients had the same rehabilitation program which focused on strength training, agility, endurance training and sport-specific training. Rehabilitation started on the second day post operation, but the rehabilitation with focus on strengthening exercises started two weeks post operation. They only used closed kinetic chain exercises when doing strength training and 64% of the patients restored 90% or more of the muscle strength in the injured thigh. After rehabilitation, 94% of the patients reported no significant symptoms when doing activity at a high intensity level. 98% of patients had full flexion and 97% had full range of motion. The time from surgery to practicing sports had a range of 3-10 months and time from surgery to fully practicing competitive sports was 5-12 months.

Hartigan, Axe and Snyder-Mackler (2010) conducted a randomized clinical trial where they looked at the time needed for noncopers to pass the criteria for returning to their sports. They define noncopers as those “who do not compensate well after the injury” (Hartigan, Axe, Snyder-Mackler, 2010, p. 1). They compared two different interventions before surgery to observe any differences in quadriceps strength and functional outcomes. The patients were randomized into two groups: strength group (STR group) and perturbation and strength group (PERT group). The patients completed ten sessions before surgery. They trained the injured leg with exercises emphasizing the quadricep muscles. However, they suggest that training the quadricep muscles both before and after surgery may not assure quadricep strength gain for all patients. After surgery they all received the same rehabilitation with emphasis on quadricep strength but without any perturbation involved. They found no differences in the

two groups postoperatively, except that patients from the STR group were able to hop faster at 12 months postoperatively, and patients from the PERT group rated their knee function more favorably. They claim that noncopers may need more time to return to sports, and that there were eight patients who were not able to return due to different reasons.

Another study (Eitzen, Moksnes, Snyder-Mackler & Risberg, 2011) used a five week-program early after ACL injury in patients participating in level I and II sports (including sports such as soccer, football, basketball, tennis and skiing) where level I is the highest level in sports, and level IV is sedentary activity (Eitzen, Moksnes, Snyder-Mackler & Risberg, 2011). Most injuries occurred playing soccer, handball or skiing. 100 patients were included in a three phase-program, where phase two was the five week-program. In the first phase the emphasis was on resolving swelling and ROM deficits. Patients were excluded if the impairments were not eliminated within the first three months of the initial phase. In the strengthening five week-program they combined strength training with perturbation and neuromuscular training. One of the main goals was to restore muscle strength after injury. After completing the program they were tested to determine whether reconstruction was necessary or not. 64% went through ACL reconstruction (ACLR) while the remaining 36% did not. Those who went through ACLR were younger than those who did not, with mean ages at 24.5 and 29.0, respectively. The ones who wished to return to sports quickly wanted ACLR, and 81% of the surgically treated were active in level I sports. None of the patients experienced pain while performing strength exercises, but almost 5% of the patients (out of 98 patients, two were lost to follow-up) experienced swelling and pain when performing plyometric exercises. The knee function of the patients was significantly improved after the five week-program. Only 3,9% of the patients attending the post tests had progressive swelling or pain. This could point to the fact that those who did not experience any complications, were in fact ready to return to sports.

#### **4.0 DISCUSSION**

Results showed that the five most commonly used strength exercises in rehabilitation were squats, leg extension, knee flexion, leg press and step ups/step downs.

## 4.1 Exercises and why they are effective

### Squat variations

A squat is an exercise used in several rehabilitation protocols after an ACL injury. It has been shown that this type of exercise produce a strong hamstring-quadriceps coactivation. One way to enhance this activation is performing squats on an unstable platform. This can be done by just focusing on doing vertical squats on the platform or other alternatives that can be more challenging. The athlete may for example get the instruction to squat between the angles 25° and 30° while trying to stabilize the platform and prevent it from moving as much as possible. When this task is mastered, perturbations can be added for more challenge (Wilk, Arrigo, Andrews & Clancy, 1999).

### Leg extension

Full joint stability is crucial for successful recovery of the injury and therefore executing exercises that are not injurious for the knee, and will amplify the knee extensor, is very important (Grodski & Marks, 2008). It is also important to pay attention to pain and inflammation when doing rehabilitating exercises as pain may cause the quadriceps to not fully activate (Wilk & Arrigo, 2016). There is broad agreement on how important training the quadricep muscles is when rehabilitating from ACL injury, and that there are several reasons for this conclusion. Many agree on the fact that the patient must achieve at least 85% quadriceps strength compared to the opposite leg as a criterion for returning to sports (Ueda, Matsushita, Araki, Kida, Takiguchi, Shibata, Ono, Ono, Matsumoto, Takayama, Sakai, Kurosaka & Kuroda, 2017). One of the exercises that are widely used to strengthen the quadriceps is leg extension. This type of exercise is beneficial for the knee and to rehabilitate from the injury. Something to take into consideration while doing leg extensions is the ROM. One study found that extending the knee over 30° led to joint swelling (Grodski & Marks, 2008).

### Knee flexion/leg curl

According to Kvist (2004) “the role of the hamstring muscles are to flex the knee joint, increase joint compression and to pull the tibia backwards through a posterior shear force at flexion angles greater than 20°” (Kvist, 2004, p. 271). Knee flexion is used in many rehabilitating protocols, and Wilk and Arrigo (2016) reported that a gradual restoration of full knee flexion by passively pushing the heel to the glutes, is a good way to rehabilitate and

achieve full ROM. This must happen gradually from 0-90° in the first week, followed with 1-100° seven to ten days after surgery. Kvist (2004) claims that the gastrocnemius muscle may not get enough attention, as it is an important stabilizer for the knee. This also takes part in flexion of the knee.

#### Leg press

Muscles activated during leg press are the quadriceps, hamstrings, glutes and gastrocnemius. These muscles minimize the pressure on the anterior part of the patella and shear forces on the anterior part of the tibiofemoral joint, which is beneficial when rehabilitating an ACL injury. When doing this exercise, you can vary between different stances which will result in bigger activation in some muscles (Escamilla, Fleisig, Zheng, Lander, Barrentine, Andrews, Bergemann & Moorman, 2001).

#### Step ups/step downs

Step ups and downs are used to let the patient control their hip and pelvis, and is often important in rehabilitation in women (Wilk, Arrigo, Andrews & Clancy, 1999). This exercise may also be performed as more challenging by placing one foot on a piece of foam to enhance neuromuscular control (Wilk, Arrigo, Andrews & Clancy, 1999). Step downs also enhance neuromuscular control (Hartigan, Axe & Snyder-Mackler, 2010) and this exercise is often used in rehabilitation processes to strengthen the muscles around the knee joint, as well as to provide stability.

### **4.2 Phases regarding rehabilitation and surgery**

Wilk and Arrigo (2016) claim that a 21 days preoperative phase is sufficient, but this may be inaccurate because there are factors that must be taken into consideration, such as individual differences and graft type used in the case of surgery. They do mention that 21 days *often seem to be* appropriate. In a study comparing two groups they found no significant difference between patients who went through early versus delayed surgery when both groups underwent an accelerated rehabilitation approach (Meighan, Keating & Will, 2003). This may also differ between athletes and non-athletes.

### **4.3 Accelerated versus non-accelerated approaches**

Wilk, Arrigo, Andrews & Clancy (1999) inform that an accelerated program is quite aggressive and places high demands on the knee joint, and that accelerated programs are for serious and competitive athletes. Shelbourne and Nitz (1990) found that their accelerated program was more successful than the non-accelerated, and Wilk and Arrigo (2016) also claim that patients who follow an accelerated rehabilitation approach experience less pain, and are able to return quicker to sports than those who follow a more conservative approach (Wilk & Arrigo, 2016). In addition, the rehabilitation process being much shorter for the athlete, it reduced patellofemoral joint symptoms such as pain (Shelbourne & Nitz, 1990). Draper and Ladd (1993) used a moderately accelerated program and found it to be effective. Although they say that many protocols focus on the patient returning to sports as fast as possible, it is important that the patient reports subjective perceptions. It seems that an accelerated approach may not be necessary unless you're dependent on returning to sports as soon as possible. This may point to the fact that a non-accelerated approach is suitable for non-athletes who need to regain function, but is able to do this over an extended period of time.

### **4.4 Open versus closed kinetic chain - which one is better?**

There is debate regarding open kinetic chain exercises (OKC) and closed kinetic chain exercises (CKC). Nakayama, Shirai, Narita, Mori and Kobayashi (2000) used exclusively CKC in their protocol, and over half of the patients regained 90% of their strength. While some have concluded that CKC exercises are better, other findings show that there is no significant difference. Kvist (2004), on the other hand, found that a combination of both OKC and CKC resulted in significantly stronger quadriceps. Wilk and Arrigo (2016) also claim that a CKC will be more beneficial because it minimizes ACL stress, while the OKC can increase looseness. In addition they claim that CKC can promote normal muscle activation and coactivation, maintain or promote muscle strength and endurance and increase activation of the quadriceps without causing knee strain. It may also activate the gastrocnemius muscle which serves as a protector, while providing for stronger hamstrings activation that protects the knee joint (Wilk & Arrigo, 2016). It seems that the papers that found one to have a better effect on ACL rehabilitation than the other, did find CKC to be the most effective one. This is interesting due to the fact that one of the most used exercises for ACL rehabilitation is leg extension, which is an OKC exercise. Shelbourne and Nitz (1990) for instance, report that

they emphasized CKC exercises as OKC exercises apply relatively larger pressure to the joint with less compression. Whereas in CKC, the entire limb carries the load as the foot is fixed to a surface, which is less injuring. In the same study, Shelbourne and Nitz (1990) say that patients in the accelerated program would do leg extensions the first day post operation and they highlight this exercises saying that in previous protocols where extension was not used as much, the patients would report pain and other problems. According to several articles (Morrissay, Hudson, Drechsler et al. (2000), Yack, Cynthia, Collings et al. (1993)), OKC exercises (when training the knee extensors) can displace the tibia on the femur which can cause looseness in the knee joint. However, Grodski and Marks (2008) makes the notion that OKC exercises are most efficient (and not as damaging) when being executed at some specific angles in the knee and that these angles are difficult and painful for people who have just undergone ACL surgery. These studies show that some of the most used exercises in ACL rehabilitation might be harmful, especially if not executed correctly, but when performed in controlled settings with help from a clinician, the thought is that both these types of exercises may be effective and maybe even crucial to regain normal function. It seems that more research on this topic is necessary.

#### **4.5 Perturbation training**

Eitzen, Moksnes, Snyder-Mackler and Risberg (2011) used perturbation training combined with strength training in their program to enhance muscle strength and neuromuscular responses. Another two papers (Wilk & Arrigo, 2016, Chmielewski, Hurd, Rudolph, Axe & Snyder-Mackler, 2005) show that perturbation training is used when performing strengthening exercises or other exercises. This method is used to increase neuromuscular control and may be beneficial for the patient's recovery. The perturbation is often performed by the clinician on the patient while he or she is performing exercises. Hartigan, Axe and Snyder-Mackler (2010) found that a significantly greater number of patients from the strength training group rated their knee function to be less than 90% compared to the group receiving perturbation combined with strength training six months after reconstruction. However, others show that the use of perturbation have no significant effect compared to programs without this type of training (Arundale, Capin, Zarzycki & Smith, 2018). Because some experience great effects from using perturbation, there is reason to believe that including this in the

rehabilitation program may indeed help the patient in his or her recovery, and that excluding this may, in some cases, prevent the patient from fully recovering.

#### **4.6 Return to sport**

Wilk and Arrigo (2016) claim that the seriousness of the injury often is forgotten since it's so common, especially in the athletic world. 40-90% of patients develop osteoarthritis 7-12 years postinjury, and the injury may cause many athletes to never return to their previous level of play. For instance, only 78% of NBA players return to sport after getting injured, and football players may reduce their career by up to two years. Return to sports may depend on many factors and not only the success of the rehabilitation. Such factors may be psychological. For instance, fear of re-injury may cause athletes to not return (Wilk & Arrigo, 2016), and patients with a higher degree of fear are less likely to return to sports (Arderm, Webster, Taylor & Feller, 2010). This is not emphasized in this review, and may be crucial for the success of the program and for the athlete to return to sports confidently. The term "return to sport" is unclear in the literature. Thomeé, Kaplan, Kvist, Myklebust, Risberg, Theisen, Tsepis, Werner, Wondrasch and Witvrouw (2011) say that a successful return to sport in the short term after ACL injury means that there is low risk of re-injury, and that a successful return to sport in the long term means that there is low risk of developing knee osteoarthritis.

#### **4.7 Female and male athletes**

Women are more prone to ACL injuries than men (Wilk, Arrigo, Andrews & Clancy, 1999), and there are different reasons for this. Wilk and Arrigo (2016) report that there are findings saying that female basketball players are eight times more likely to injure their ACL compared to male players, and that female soccer players are six times more likely to get injured than men. They also report that most of the ACL injuries in women occur in non-contact situations. According to Wilk and Arrigo women have "increased genu valgum alignment, a poor hamstring-quadriceps strength ratio, poor hip strength, running and landing on a more extended knee, a quadriceps-dominant knee posture, and hip/core complex weakness" (Wilk & Arrigo, 2016, p. 207). They also claim that the menstrual cycle may play a role in the injury rate. This means that females might need a slightly different rehabilitation to take these findings under consideration and to provide an effective rehabilitation process.

For instance, women must be taught to control their valgus moment during activity to prevent injury. Ardern, Webster, Taylor & Feller (2010) found that women were less likely to return to sports within 12 months compared to men, even though their intentions to return were the same as for the men. There should be more research regarding women and why they are more exposed to injuries, and the fact that their return to sport rate is lower than in men.

#### **4.8 Young versus adult athletes**

In this review both younger and adult athletes are included. There may be differences in these two groups of athletes, and this review does not include such factors. A paper (McGuine, Post, Hetzel, Brooks, Trigsted & Bell, 2017) say that sport specialization at a young age is becoming more common, but is also associated with high rates of injury and stress. They found that those with moderate or high sport specialization sustained more injuries than those with lower sport specialization. Sport specialization has several definitions but may be defined as “intensive year-round training in a single sport at the exclusion of other sports” (Jayanthi, Pinkham, Dugas, Patrick & LaBella, 2013, p. 252). Because the injury rates are high in young athletes, this may affect the results in the papers used in this review. There may also be other factors affecting the results and causing differences between the two groups of athletes.

#### **5.0 STRENGTHS AND LIMITATIONS**

This review includes exclusively athletes because this is a homogeneous population that may differ in many ways from non-athletes. The guidelines for rehabilitation may also vary between athletic and non-athletic patients. Athletes will want to return to their sport as soon as possible, and depend on an effective rehabilitation program to do so, whilst non-athletes may not depend on such a speedy recovery even though the goal is to regain normal function in all patients. This is where one can argue for an accelerated versus non-accelerated approach and whether it may be more beneficial for someone to do an accelerated, but for others a non-accelerated may be more suitable.

However, this review may be criticized for not including all exercises used in a rehabilitation program. The emphasis is only on strength exercises, and the findings listed must not be



viewed as a universal standard because a serious injury like the ACL injury must be treated with multiple exercises and suitable approaches to reach the rehabilitative goals. There are also different ways to reach these goals, and some approaches may focus more on other exercises, or other ways to achieve increased balance, agility, neuromuscular control and so on. There are also few main papers used, and this may point to the fact that other strength exercises are effective as well, but not represented in the literature regarding only athletes. On the other hand, this review presents a group of patients who may need specific rehabilitation approaches, and this could be one reason the literature is quite short on this topic.

For further research, rehabilitation in both athletes and non-athletes could be studied to observe differences that may exist, and including all factors that are important for a successful recovery.

## **6.0 CONCLUSION**

This review provides information about factors in rehabilitation of ACL injuries in athletes. Although many different exercises and approaches used in rehabilitation protocols exist, the most commonly used strength exercises in treating ACL injuries are squats, leg extensions, knee flexions, leg presses and step ups/downs. These are all effective on training the lower extremity and are used in various programs because they may help the patient recover and regain strength and function. These may be used in all programs, but this review studied exercises used on athletes with this specific injury.

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