

Received: 2019.10.27  
Accepted: 2020.02.18  
Available online: 2020.03.23  
Published: 2020.05.12

# Outcomes Following Arthroscopic Single and Double Bundle Anterior Cruciate Ligament (ACL) Reconstruction Supported by the Comprehensive Early Rehabilitation Program (CERP)

Authors' Contribution:  
Study Design A  
Data Collection B  
Statistical Analysis C  
Data Interpretation D  
Manuscript Preparation E  
Literature Search F  
Funds Collection G

ABCDEF G 1 **Rafał Trąbka**  
ABCDEF 1 **Tomasz Maicki**  
DE 2 **Paweł Kamiński**  
ADE 2 **Agata Pawełczyk**  
DE 2 **Paweł Zieliński**  
ABCDEF G 1,2 **Magdalena Wilk-Frańczuk**

1 Clinic of Rehabilitation, Faculty of Health and Sciences, Jagiellonian University Medical College, Cracow, Poland  
2 Department of Orthopaedic, Cracow Rehabilitation and Orthopaedic Centre, Cracow, Poland

**Corresponding Author:** Magdalena Wilk-Frańczuk, e-mail: [magdalena.wilk-franczuk@uj.edu.pl](mailto:magdalena.wilk-franczuk@uj.edu.pl)  
**Source of support:** Departmental sources

**Background:** The aim of this study was to compare the level of functional condition in patients who had rehabilitation with the comprehensive early rehabilitation program (CERP) following either single bundle (SB) or double bundle (DB) anterior cruciate ligament reconstruction (ACLR) using semitendinosus-gracilis tendon graft (ST-G) method. We hypothesized that 12 weeks after reconstruction followed by a rehabilitation program, there would be a difference in clinical results and functional activity between patients.





**Material/Methods:** This study included 94 patients who had rehabilitation with CERP after knee surgery for a knee injury from a recreational sport. There were 49 patients in Group 1 (mean age, 36.5 years) who had CERP after SB ACLR, and 45 patients in Group 2 (mean age, 35.6 years) who had CERP after DB ACLR. Functional condition was tested using the Lysholm Knee Scoring Scale, and knee stability was measured using KT-2000. The first examination was performed before CERP and the second examination was performed 12 weeks later.

**Results:** The level of functional condition in both groups was similar before rehabilitation with CERP, with no significant difference ( $P < 0.958$ ) and was considered relatively low. In the second examination, 12 weeks after starting CERP, the patients improved in both groups. The improvement was larger in the SB ACLR Group 1 than in the DB ACLR Group 2. The difference was significant ( $P < 0.005$ ). However, the patients in Group 2 achieved better knee stability scores in the KT-2000 examination than the patients in Group 1. The difference was significant ( $P = 0.035$ ).

**Conclusions:** We found that the patients from both groups after 12 weeks of CERP achieved an improvement in stability and functional activity within normal limits. However, SB ACLR was more effective than DB ACLR in terms of the level of functionality achieved with CERP but was less effective in terms of knee stability.

**MeSH Keywords:** **Acute Pain • Knee Injuries • Muscle Stretching Exercises • Physical Therapy Modalities • Range of Motion, Articular**

**Full-text PDF:** <https://www.medscimonit.com/abstract/index/idArt/921003>

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## Background

Anterior cruciate ligament (ACL) injury happens most often when doing different sports: contact sports like team games and non-contact sports like tennis or skiing. According to the Scandinavian ACL registry, ACL injuries occur in 6 per 1000 patients per year; 70% are sustained during sporting activity with an incidence rate of 85 per 100 000 in the at-risk group of persons age 16 to 39 years old. Injury rates are 4 times higher in females than males [1]. Over 100 000 ACL reconstructions are performed per year in the United States [2] making ACL reconstruction a common orthopedic procedure.

The main damaging mechanisms are lower limb abduction with flexion and internal rotation, excessive knee extension with internal rotation, lower limb adduction with flexion and external rotation, and direct injury of the lower leg with translation within the sagittal plane [3–9]. This damage also reduces the functional condition of the patient after ACL injury [8,9].

The functional condition of the patient after ACL reconstruction is one of the most important measurements that can help demonstrate the superiority of various surgical techniques. Functional condition is associated with patient well-being, with a particular emphasis on pain, ability to walk, and ability to perform everyday activities. The assessment of functional condition uses various research tools for objective measurements of mobility and range of motion [1,2] as well as subjective assessment by the patient using functional state scales [3–5]. In modern medicine, in addition to objective methods of assessment, it is widely appreciated that the subjective assessment by the patient of their own health is considered an effective evaluation of surgical treatment.

However, many clinical reports of the effectiveness of the 2 methods of ACL reconstruction (ACLR), single bundle ACLR (SB ACLR) and double bundle ACLR (DB ACLR), often only use objective measures [6] or only use subjective measures based on patient opinions [7]. This may lead to an incomplete evaluation of the effectiveness of the patient's treatment [8]. Therefore, further research in this area is needed on how to best assess the effectiveness of operations using both objective and subjective knee scores [9].

In the literature, the functional anatomy and biomechanics of ACL have been reviewed in numerous reports. SB ACLR has been widely used for years, whereas DB ACLR has become a popular choice. The DB technique was described for the first time in 1983 [10], and it is believed by many authors to allow for better rotational stability and pivot resistance compared to the anatomical SB method [11–15].

A meta-analysis of randomized controlled trials conducted in large clinical centers around the world did not, however, clearly confirm the superiority of DB ACLR over SB ACLR as measured using differentiated objective and subjective knee scores. However, a recent large meta-analysis of randomized controlled trials showed that 71% of studies (10 out of 14 studies) showed better results for DB ACLR than SB ACLR for objective and subjective knee scores [16]. Clinical studies have also reported that DB ACLR showed better kinematics for restoring intact knee kinematics, including translations and rotations [17–21]. Biomechanical studies *in vivo* have shown that patients operated on using the DB ACLR method achieved higher control of rotational stability [22].

There are, however, many scientific articles in which no explicit superiority of DB ACLR or SB ACLR was found by objective and subjective knee scores. This has been confirmed by large clinical studies conducted for both early and long-term follow-up [23–26]. In one of the latest clinical studies, there were no significant differences between the subjective knee scores, static stability, functional performance tests, pivot shift test, and isokinetic muscle strengths in patients who received either the anatomical SB or the DB ACLR surgery at 2-year follow-up [27] or 3-year follow-up [28].

On one hand, we can see that the discussions and disputes about the effectiveness of ACL reconstruction with available SB and DB procedures are still ongoing and there is no clear answer as to which of the operating methods is more effective in the functional results of knee recovery. On the other hand, functional problems with the knee joints results from instability following ACL injury and occurs mainly during turning and changing of direction. This can become an obstacle when doing physical activities, especially sports, and may even limit activities of daily living (ADL) to a basic functional level. Studies have shown that 44% of patients develop a significant impairment of functions, affecting the ability to perform daily activities. Most of the patients with an inefficient or torn ligament can walk normally, but doing basic sports is possible only when moving forward and backward in a straight line [8]. In turn, repeated secondary injuries lead to meniscus damage, and inflammation leads to degenerative changes in the joint [9]. Loss of anterior-posterior stability with inefficient ACLR causes changes in the biomechanics of the whole joint, which results in disorders of proprioception and function of the lower extremity.

Therefore, the need for a comparative assessment of these 2 ACLR methods is still valid. To compare the results of reconstruction with SB ACL versus DB ACL, we planned an experiment in which the study groups were carefully selected for testing with inclusion and exclusion criteria. In our study,

**Table 1.** Characteristics of the tested groups.

Feature	Group 1		Group 2		Statistical significance P-value
	x	SD	x	SD	
Age (years)	36.5	12.0	35.6	7.2	0.625
Height (m)	166.0	9.1	166.8	7.3	0.424
Body mass (kg)	66.6	13.4	67.1	10.2	0.413
BMI (kg/m <sup>2</sup> )	24.1	4.9	24.2	2.9	0.589

x – mean value; SD – standard deviation; BMI – body mass index. Significant difference within the groups ( $P < 0.05$ ).

the protocol for treatment and rehabilitation of all patients was in accordance with the CERP used in other studies [8,29].

The aim of this study was to compare the clinical results and functional performance of patients who suffered a knee injury while taking part in recreational sports, and to follow SB versus DB ACLR using ST-G (semitendinosus-gracilis tendon graft) methods followed by the standard CERP used in our center [6]. We hypothesized that 12 weeks after reconstruction there would be a difference between clinical results and functional activity between patients who underwent reconstruction SB ACL versus DB ACL.

## Material and Methods

This study conformed to the Declaration of Helsinki, and the study protocol was approved by the Regional Medical Ethics Board of Physicians in Krakow, Poland (no. 91/KBL/OIL/2010). All patients signed an informed consent before participating in the study.

### Participants

The study participants included persons who participated in recreational sports and who after an ACL injury qualified for operative SB ACLR or DB ACL ST-G reconstruction. There were 94 patients who after knee injury had ACLR surgery and 12 weeks of CERP rehabilitation in St. Raphael Hospital in Cracow. Patients were divided into 2 groups depending on the type of the ACL operation. Group 1 patients had SB ACLR and consisted of 49 patients (17 females and 32 males; average age, 36.5 years). Group 2 patients had DB ACLR and consisted of 45 patients (17 females and 28 males; average age, 35.6 years).

In both groups there were no patients with obesity as measured by body mass index (BMI) as class II or class III, the highest BMI in class I in Group 1 was 33.9 kg/m<sup>2</sup> and in Group 2 was 31.2 kg/m<sup>2</sup> (Table 1).

In both groups, patients with right leg dominance constituted the majority of patients (71.4% in Group 1 and 66.7% in Group 2). There were 14 patients (28.6%) with left leg dominance in Group 1, and 15 patients (33.3%) in Group 2. In Group 1 there were 23 patients (46.9%) who had the left leg operated on and 26 patients (53.1%) who had the right leg operated on. Similarly, in Group 2 there were 21 patients (46.7%) who had the left leg operated on and 24 patients (53.3%) who had the right leg operated on. We found that the majority of patients had sustained an injury during sporting activities (73.5% in Group 1 and 77.8% in Group 2) and in so called non-contact sports (77.6% in Group 1 and 68.9% in Group 2).

Inclusion criteria was as follows: total ACL damage; qualified for operative treatment (primary ACL single or double bundle reconstruction with the ST-G method); full logical verbal contact; consent to participate in the study.

Exclusion criteria was as follows: concurrent damage of another ligament of the knee joint more than to a second degree or a recent injury of a different joint or of the other lower extremity; damage of articular cartilage III/IV; condition following a menisci operation; post-operative complications influencing the rehabilitation process; stopping of the treatment program at the request of the patient.

### Methods

The time period from the injury itself to the operation was on average 4 months (chronic injury). In the evaluation, the following items were taken into account: personal data, domination of the lower extremity, type of injury, type of reconstruction, time of starting and finishing the rehabilitation program, and BMI index.

To evaluate the level of functional condition, we used the Lysholm Knee Scoring Scale, and the KT-2000 for the knee stability. The first examination was performed before the ACLR, and the second examination was performed 12 weeks after the reconstruction. The Lysholm Knee Scoring Test measures

the functional condition of the knee joint of the patient [29]. It describes 6 parameters such as limping, knee loading, climbing stairs, the ability to squat, gait evaluation (instability and pain), swelling and thigh muscle loss after the operation. The maximum score is 100 points which means a 100% efficiency of the operated on lower extremity. The following criteria were adopted: a very good result was >90 points, a good result was 90–84 points, a sufficient result was 83–65 points, and a poor result was <65 points.

To evaluate the level of the knee stability we used the KT-2000 arthrometer. performed using the same position of the patient and lower extremity as is used in the Lachman test. For this measurement, the most common criteria of knee stability evaluation following ACLR are: a result less than 3 mm indicates a stable knee joint, a result between 4–5 mm indicates a limit to the normal state, a result between 6–10 mm indicates the onset of instability, a result more than 10 mm indicates an unstable knee [14]. Many authors stress that an evaluation of knee stability with the KT-2000 arthrometer is characterized by a high clinical reliability, repeatability, and measurement sensitivity [15,16].

## Methods of ACLR

### *Single-bundle ACL reconstruction (SB ACLR)*

In Group 1, SB ACLR was performed, which involved drilling 2 bone channels (1 in the femur and 1 in the tibia) and placing 1 tendon band in each bone tunnel; an anatomical SB ACLR was viewed through an anteromedial portal. The tunnel was positioned at the mid-condylar position using the ruler technique [30].

### *Double-bundle ACL reconstruction (DB ACLR)*

In Group 2, DB ACLR was performed using 4-channels, which involved drilling 2 bone channels (2 in the femur and 2 in the tibia) and placing 2 tendon bands in each bone tunnel, using standard operating procedures [8]. In order to reestablish native anatomical biomechanics of the damaged ligament, the fixation method provides a double bundle configuration of the ligament using a single tunnel at each of the femoral and tibial attachment sites. A double, triple, or quadruple graft was prepared, and a femoral socket and a tibial tunnel, in the form of axially elongate openings, are created for ligament reconstruction in the standard fashion.

After the procedure, all 3 incisions (2 femoral and 1 tibial canal) were sutured after arthroscopy and after transplantation. After the operation, the patient remained in the hospital for 2 days. From the first hours after surgery, the patient received anti-inflammatory, analgesic, and anti-edema treatment, with

cold compresses and lower limb elevation. In the operating room, every patient received an orthosis that stabilizes the knee in extension.

### *Comprehensive early rehabilitation program (CERP)*

A comprehensive early rehabilitation program (CERP) was developed with agreement with the surgeon on the basis of surgical experience and scientific research [31,32]. CERP is based on the principles of the Polish School of Rehabilitation, so it is characterized by early application after surgery, comprehensiveness, universality (i.e., it covers all patients and at the same time), and it incorporates individualization (i.e., adjustments are made to fit the needs of individual patients) [8,9,31,32].

CERP is a staged, complex pre- and postoperative rehabilitation program. The postoperative phase lasts 12 weeks. Exercises are given for 5 days; and include 2 exercise modules. The first module comprises slightly easier exercises and is offered to patients who are recreational practitioners. The second module comprises slightly more difficult exercises and is designed for professional sports persons practicing competitive forms of sports.

The patients in our study used 1 module of exercises, and during the entire program, the patient's exercises were supervised by the same physiotherapist. The CERP was introduced to the patients at the St. Raphael Hospital in Cracow, Cracow Rehabilitation and Orthopedic Centre, and in RST Rehabilitation. However, the study patients were trained in the day program training offered at St. Raphael Hospital in Cracow, under the supervision of the first author of this article. The aim of the CERP was not only to improve the patient's functional activity, but also to prepare him or her to do physical activities at a similar level to their activity before the injury.

### *Description of the individual phases of the exercise*

Phase I was from day 1 to the second week. Exercises were done 4 times a day, 20 to 25 repetitions. Program recommendations included standing, walking, doing exercises in the orthosis, ice packs for 15 to 20 minutes, and active knee flexion in the range 0° to 30° with up to 90° at the end of week 2 (Figure 1). Then movement in a pain-free, comfortable range, with gait re-education which included learning to walk with elbow crutches with weight bearing up to 30% to 50% of total body mass. In addition, exercises for patella and knee soft tissue mobilization, such as massage of fascia and tendons, glides, and mobilization of patella. The main therapeutic goals were full knee extension, active knee flexion to 90°, gait re-education, and muscle control of the operated-on leg.



**Figure 1.** Lying back, lower limb bent in the knee joint up to about 30°, pressing the ball into the wall. (Photo: R. Trąbka.)



**Figure 3.** Strengthening the sciatic shin muscles of the thigh. (Photo: R. Trąbka.)



**Figure 2.** Knee joint movements in the range of 90° to 60° flexion with resistance using Thera Band. (Photo: R. Trąbka.)

Phase II was from the second week to the fourth week. Exercises were done 4 times a day, 20 to 25 repetitions. Program recommendations included active knee joint movements in the range of 90° to 60° flexion (Figure 2), active movement in the orthosis up to 120°, and gait re-education such as walking with crutches. The main therapeutic goals were full active knee flexion in the range from full extension to 120° normal gait without limping, and discontinuation of orthosis support.

Phase III was from the fourth to the sixth week. Program recommendations were to strengthen the sciatic shin muscles of the thigh and hamstrings (Figure 3). After the fourth week, recommendations included walking with one crutch and after the fifth week walking without the crutch indoors (e.g., a house or apartment). The main therapeutic goals were walking without crutches, normal gait pattern without limping, improvement of proprioception, and full passive and active ROM in the knee joint.



**Figure 4.** Exercises on the sensorimotor disk (Phase IV). (Photo: R. Trąbka.)

Phase IV was from the sixth to the tenth week. The main therapeutic goal was to improve gait mechanics. Recommended exercises were exercises on the sensorimotor disk (Figure 4) and eccentric training of the lower extremity in a full range on the basis of an open and closed kinetic chain.

Phase V was from the tenth to the twelfth week. Recommendation exercises were dynamic exercises on the sensorimotor disk (Figure 5). The main therapeutic goal was free running on a treadmill without limping; the recommendation



**Figure 5.** Dynamic exercises on the sensorimotor disk (Phase IV).

to start running training depended on this evaluation. Patients were not allowed to start running training if the difference in muscle strength and/or endurance between the operated-on and non-operated-on leg was greater than 30%. Patients were not allowed to restart sporting activities if the difference of muscle endurance between the operated-on and non-operated-on leg was greater than 20%.

**Phase 5: Dynamic exercises on the sensorimotor disk**

The person responsible for monitoring the study results and the person who treated the patient did not know what type of operation had been performed. From the first day following the operation, patients were instructed by a physiotherapist as to what kind of exercises they should do. Within a specified time-limit, patients visited the hospital so the person who monitored the results could take measurements and a physiotherapist could implement a treatment protocol.

**Table 2.** Results of evaluation with the Lysholm Knee Scoring Scale.

Evaluation	Group 1		Group 2		Statistical significance P-value
	x	SD	x	SD	
Evaluation 1	42.3	22.5	43.3	20.0	0.958
Evaluation 2	91.0	6.2	86.6	7.6	<b>0.005</b>

x – mean value; SD – standard deviation. Significant difference within the groups ( $P < 0.05$ ).

**Table 3.** Results of Evaluation with the Arthrometer KT-2000, 12 weeks after the operations in both groups.

Examination	Group 1		Group 2		Statistical significance P-value
	x	SD	x	SD	
1 <sup>st</sup>	10.1	2.5	10.2	5.1	<b>&lt;0.958</b>
2 <sup>nd</sup>	1.9	0.5	1.7	0.5	<b>0.035</b>

x – mean value; SD – standard deviation. Significant difference within the groups ( $P < 0.05$ ).

We conducted a comprehensive patient assessment using an objective test (KT-2000 test) and a subjective knee score (Lysholm scoring system) twice: before the rehabilitation and after 12 weeks of follow-up.

**Statistical analysis**

Qualitative variables were described using absolute abundance and relative frequencies (%). Quantitative variables were described using mean values and standard deviations. The relevance of the differences between the distribution of 2 qualitative variables was tested by chi-square test means, while for quantitative variables the Mann-Whitney test was employed. Additionally, the distribution of quantitative variables was illustrated with box diagrams in which the minimum values, maximum values, quartiles, and the medians were marked. Statistically significant results were results in which the value of the test probability ( $P$ -values) was  $< 0.05$ . Calculations were done in the program R 3.0 [16].

**Results**

The analysis of the results showed that there were no significant differences between females and males, therefore further analysis was conducted without taking gender into account.

Table 2 illustrated the results of the evaluation of the functional condition by Lysholm Knee Scoring Scale. It was found that in the first examination, the level of functional condition was similar between groups and relatively low: Group 1 at 42.3 points and Group 2 at 43.3 points. The difference was not statistically significant ( $P < 0.958$ ). In the second examination, the

patients improved in both groups, however, the improvement was larger in Group 1 at 91.0 points compared to Group 2 at 86.6 points. The difference was statistically significant ( $P<0.005$ ).

Table 3 illustrates the results of the evaluation of knee stability measured by the arthrometer KT-2000 at 12 weeks after the operations in both groups. It was found that in the first examination, the knee instability in both groups exceeded the value of 10 mm. The difference between the groups was not statistically significant ( $P=0.589$ ). In the second examination, the patients in both groups improved (none of the patients exceeded a value of 10 mm). However, the improvement was larger in Group 1 with the mean value of 1.9 mm (standard deviation 0.5 mm) than in Group 2 with the mean value of 1.7 mm (standard deviation 0.5 mm). The difference was statistically significant ( $P=0.035$ ).

## Discussion

In this study we confirmed the assumption that all patients from both groups were able, after 12 weeks of rehabilitation, to improve in stability and functional activity within normal limits. In other words, all knees were improved by ACLR compared with their pre-operative status, and the patients returned to their pre-operative activities. This means that the proposed surgical and rehabilitation treatment promoted a better quality of life for the examined patients, regardless of the type of surgery used.

However, the results obtained differed in patients operated on using SB ACLR versus DB ACLR methods. The DB ACLR method is a more invasive method of surgical treatment due to using 4 operating tunnels (2 in the tibia and 2 in the thigh), which is associated with greater tissue damage. The patients who had DB ACLR achieved better knee stability, but worse functional status than patients who had SB ACLR. Reverse results were obtained for patients who had SB ACLR. SB ACLR is a less invasive method of surgical treatment due to using 2 operating tunnels (1 in the tibia and 1 in the thigh) which is associated with less tissue damage. Patients who had SB ACLR had worse knee stability but had better functional status.

ACL injury and reconstruction are common in the United States. However, compared to the standards of other orthopedic procedures, ACLR is not predictably effective in regaining a level of functioning comparable to that before the injury. Only 60% to 70% of patients after reconstruction return to the previous level of activity, and many of them suffer to some extent from arthrosis [30]. In our study, patients from Group 1 had a very good outcome and patients in Group 2 had a good outcome in terms of the functioning of the knee joint.

On the one hand, our patients obtained better results in terms of functional activity than the results obtained by many other studies comparing efficiency of SB versus DB ACLR. On the other hand, our patients showed a similar improvement trend in terms of clinical and functional results to the results of large, randomized controlled trials directed toward the evaluation of the effectiveness of the reconstruction of SB versus DB ACLR [3–5,9].

How can we explain the spectacular results obtained by the patients in our study that are at least partly different from the results obtained worldwide? One of the most important reasons for the differences obtained in our study was the fact that the vast majority of scientific articles focused on comparing the results of reconstruction using SB or DB ACL in sports persons practicing competitive forms of sports who were injured during competitions [4,8,11,13–15,18,20]. These patients had higher initial knee functional efficiency, which may affect the obtained test results. There are few studies aimed at comparing the results of SB ACLR and DB ACLR in recreational practitioners [17,21]; these patients after surgery are usually offered a home rehabilitation program, which, as is known, can be performed systematically or not. Thus, the results will be burdened with an error related to the lack of insight into the quality of the exercises performed [6].

Another important factor in evaluating study results is the way the surgery is performed, often related to the experience of the orthopedic surgeon and the number of procedures performed by that surgeon, as well as the equipment available in the operating room of the study center. Post-operative rehabilitation algorithms used in the rehabilitation process of patients with ACL also have an impact on the assessment of effectiveness SB ACLR versus DB ACLR. In future experiments devoted to assessing this effectiveness, rehabilitation is recommended to be included in the exercise package that the patient performs at home. Therefore, it is difficult to compare the results obtained in such home projects with others in which, as in the case of the CERP used in this study, where the exercises are supervised by a physiotherapist. It is known that it is not possible to check the quality of performance of these exercises, and it is not known whether the patient did these exercises at home at all, because we rely on the patient's declaration [8,9].

Therefore, in many study reports we find statements that there is insufficient evidence to determine the relative effectiveness of SB ACLR versus DB ACLR for ACL rupture in adults; although there is limited evidence that DB ACLR has some superior results in objective measurements of knee stability and protection against repeat ACL rupture or a new meniscal injury [34].

In this context, it should be mentioned that the optimal time for ACLR is debatable because both early and late operations

have shown negative clinical results [33,34]. ACLR should be done within 12 months from the date of injury to avoid further damage to the menisci and articular cartilage. Early reconstruction (within 3 weeks following an injury) can lead to an increased risk of arthrofibrosis, and if it is done during this period, certainly it should be followed by a fast-track rehabilitation program [8,9]. Shelbourne et al. in their study of 169 young sports persons claimed that patients having ACLR performed in the first 7 days after an injury were more susceptible to arthrofibrosis than when the operation was delayed for 3 weeks or more [35]. This study also confirmed that patients who had ACLR done from 1 to 3 weeks after the injury in conjunction with a fast-track rehabilitation program had less arthrofibrosis in comparison to a control group treated conventionally. Almekinders et al. noted in their study less range of motion (ROM) in patients following a ACLR done in the first month, however, there were no significant differences observed at the end of the rehabilitation process in comparison to patients who had the operation done later than a month [36]. Passler et al. reported a significant increase in the incidence of arthrofibrosis after an injury in the first 7 days (17.6%) in comparison to a group evaluated after 4 weeks (6.1%). In that study, the operation was done on average about 4 months following injury. Physiotherapy was implemented in both groups from the first day after the operation and it included exercises strengthening the muscles of the knee joint in closed kinetic chains and exercises improving ROM [37]. Norouzi et al. suggested doing exercises in a closed kinetic chain would be better than in an open kinetic chain in patients following ACLR to provide functional stability for the knee joint [38]. Yabroudi and Irrgang suggested that rehabilitation after ACLR should include control of postoperative pain and edema, protection of the healing graft, restoration of full ROM symmetrical to the other knee, strengthening of the knee, hip and trunk stabilizers, strengthening of neuromuscular control, and gradual transition to activities needed to do sports again [39]. At an early rehabilitation stage, exercises strengthening the quadriceps femoris muscle should not be done with full knee extension to prevent too much load being placed on the healing tissue [40]. All the aforementioned suggestions were taken into consideration during the planning of the treatment program for our study. Additionally, we offer individualize exercises for each patient, because our CERP contains 2 exercise modules: 1) module contains slightly easier exercises and is offered to recreational practitioners; 2) module contains slightly more difficult exercises and is designed for professional sports persons practicing competitive forms of sports. The patients examined here used only the first module/packet of exercises because they were recreational practitioners.

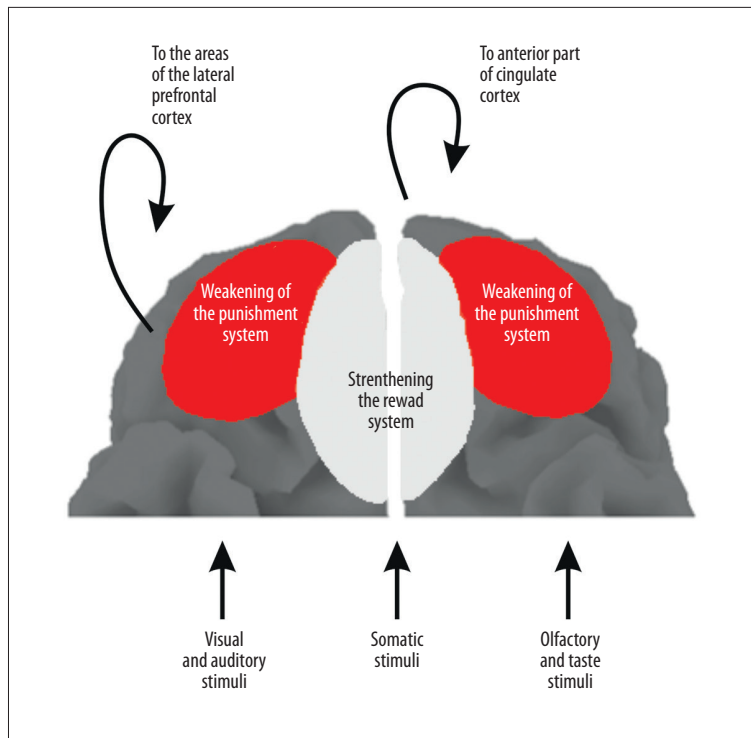
The impact on the effectiveness of rehabilitation can also be associated with the time of rehabilitation commencement. ACL injuries are a frequent trauma of the knee joint in persons

leading an active lifestyle. It is important that members of any medical healthcare team accepted an evidence-based approach to diagnosis, surgical treatment, and postoperative rehabilitation in patients following ACLR surgery. The mechanism of ACL injury and the diagnostic test is consistent within the literature, but there are inconsistencies with regard to surgical techniques and postoperative procedures. However, rehabilitation plays an important role in functional recovery. Therefore, appropriate rehabilitation of the patient after ACLR surgery is necessary and its goal is to achieve good functional results in order for the patient to be able to continue activities that were previously performed, at a comparable level. Early postoperative activity allows muscle strengthening for early restoration of knee function [41]. The introduction of early rehabilitation, compared with the subsequent implementation of exercises, is more effective in accelerating the healing process [42] and better functioning, even after 2 years post ACLR [43].

Dragicevic-Cvjetkovic et al. described the influence of rehabilitation on the muscle mass of the thigh and the functional condition of the knee joint as determined by the Lysholm Knee Scoring test. Patients were divided into 2 groups, 35 persons in each group. Group A received “aggressive” and “fast-track” postoperative rehabilitation, whereas Group B received a standard rehabilitation program. The authors claimed a significant difference in thigh circuit and functional condition of the knee joint between the groups in favor of Group A, which obtained better results [42]. It is worth noting, however, that the module “aggressive” and “fast-track” postoperative rehabilitation is offer to professional sports persons practicing competitive forms of sports, who differ in limb performance from recreational practitioners.

Finally, there are a lot of publications on the treatment of ACL injury [36]. But still there is no generally approved and recommended management algorithm available [35,37,38]. In our study, we used 2 operating techniques and an intensive CERP rehabilitation program which was common to all study patients who were evaluated, and the rehabilitation was confirmed as effective. We can therefore suggest that to achieve positive treatment results, a complex pre- and postoperative rehabilitation program is needed, similar to our CERP, which is based on the modern views on symptom formation, according to microgenetic theory [44,45]. In this context, a program of individual exercises was offered to meet the needs of patients. The program was applied based on the patient’s pain limit, and was strengthened by the reward system and weakened by the punishment system in the brain, a significance consideration of CERP (Figure 6 [45]). Thanks to this feature, patients eagerly exercise and are motivated to overcome the difficulties and inconveniences associated with recovering knee health and functional fitness.





**Figure 6.** The reward/penalty system: the medial part involves the processing of the reward, and the lateral part involves the processing of the penalty. Source: Paçhalska et al. [45].

To sum up, we can conclude that proper treatment that takes into account professionally carried out ACLR and a properly selected rehabilitation program allows patients to achieve, after 12 weeks the knee stability and functional activity, knee function at a normal level. However, given the same CERP, the method of SB ACLR was more effective in improving the level of functionality than DB ACLR, and less effective in the knee stability. Relatively, the method of DB ACLR was less effective in improving the level of functionality than SB ACLR, and more effective in the knee stability. Therefore, we confirmed our hypothesis that 12 weeks after reconstruction there would be a difference between clinical results and functional activity of the patients in these 2 groups.

A team approach to operational procedures and standards for pre- and postoperative management, as well as the incorporation of CERP, will be helpful in conducting further research on the effectiveness of both operational methods SB ACLR and DS ACLR.

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## Conclusions

We found that the patients from both groups achieved an improvement in stability and functional activity within normal limits. However, the method of SB ACLR was more effective than DB ACLR in the level of functionality, and less effective in knee stability.

## Acknowledgments

We would like to thank all the patients for participating in the study.

## Conflict of interest

None.

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