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ORIGINAL PAPER

THE EFFECTIVENESS OF REHABILITATION PROCEDURE AFTER THE RECONSTRUCTION OF THE ANTERIOR CRUCIATE LIGAMENT ACCORDING TO THE NORWEGIAN PROTOCOL

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ABSTRACT

Introduction. In the 1970s and 1980s, the rehabilitation program after anterior cruciate ligament (ACL) reconstruction recommended that patients' limbs should be immobilized from 2 to 4 weeks. After such a period, the patient would be wearing a stabilizer until the end of the 3rd or 4th month. The limb could not be strained for 6 weeks.

Aim. The aim of this paper was to present a Norwegian rehabilitation protocol after ACL injury and to show its effectiveness through examining the muscle strength on the Biodex system 3 Pro after periods of 3 and 6 months following the reconstruction.

Materials and methods. The rehabilitation protocol described in *Physical Therapy* No. 6 Vol. 87 was employed. 18 patients (5 women and 13 men) were rehabilitated after reconstruction with semitendinosus and gracilis tendon grafts. All patients were rehabilitated from 2008 to 2009 in the Stefan Bołoczko Motor Rehabilitation Center, located in the Olsztyn Higher Education Institution. After periods of 3 and 6 months, these patients underwent isokinetic muscle strength test. The Biodex system 3 Pro was used.

Results and Discussion. Patients rehabilitated according to the described protocol reached an average value of muscle strength between an operated limb and a healthy one amounting to 16.8% for extensors and 11.3% for flexors after 3 months following ACL reconstruction. This result allowed them to start a running program. After

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6 months, the average value of muscle strength for extensors was 6.15% and 4.45% for flexors. This also allowed these patients to practice appropriate sport disciplines. **Conclusions.** The rehabilitation performed according to the Norwegian protocol speeds up regeneration of muscle strength after periods of 3 and 6 months, which enhances the patients' quicker recoveries with respect to their daily functioning and physical activities. The aforementioned rehabilitation procedure does not have any negative effects, provided that patient, physician and physiotherapist cooperate closely with each other.

Key words: anterior cruciate ligament (ACL), rehabilitation protocol, proprioception

INTRODUCTION

The anterior cruciate ligament (ACL) is an intra-articular, but extrasynovial structure, from 3.7 cm to 4.2 cm long and 5 mm thick on average. The ACL attaches in a fan-like form to the posteriomedial wall of the lateral femoral condyle. Next, it runs down, anterially and posteriomedially. Turning by 90°, it attaches to a tibial plateau in the tuberculum mediale area. The sizes of this ligament are varied depending on a type of build, shape, head of the femur, bone thickness, and shape of the tibial plateau [10].

The ACL consists of bundles: the anteromedial bundle, a bigger, posterolateral bundle and the smallest intermediate bundle [4]. Arthroscopy for ACL reconstruction has been in use since the 1980s. Currently, the following autografts are used in this kind of treatment: a free autologous central one-third bone-patellar-tendon-bone (BPTB) graft, semitendinosus (ST) and gracilis (GR) muscle tendons, rectus femoris tendon and iliotibial band (ITB). Allografts are also used, including: Achilles tendon with fragments of heel bone, pattelar ligament, flexor ligament (tibialis anterior muscle) or synthetic grafts [1, 6, 7].

In the 1970s and 1980s, the rehabilitation program after ACL reconstruction recommended that the involved limb should be immobilized from 2 to 4 weeks. After such a period, the patient would be wearing a stabilizer until the end of the 3rd or 4th month. The limb could not be strained for 6 weeks. The first muscle strength test was carried out 6 months following the reconstruction, the next one after 12 months. If the difference between the operated upon and the healthy limb was less than 20%, then a patient was allowed to do unlimited physical activities. In 1986 a protocol was introduced which allowed patients to perform the passive motion immediately after treatment. It was possible thanks to a continuous passive motion (CPM) device (Fig. 1), which helped to avoid long-lasting immobilization [2]. Today, the employment of a CPM device is a controversial issue. With the earlier introduction of motion and strain on an operated limb into the rehabilitation program, the advantages of this device are becoming less significant. Few current research programs show crucial, long-term benefits as a result of using the aforementioned device [3].

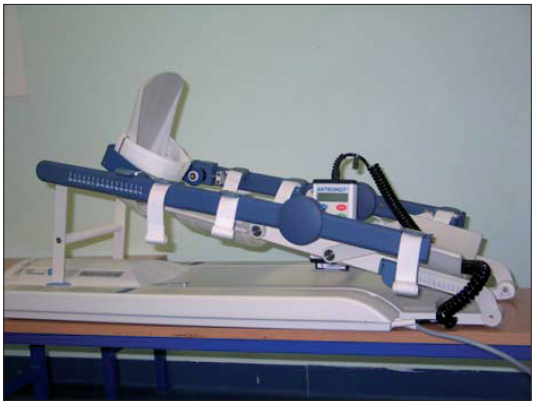

Fig. 1. CPM (Continuous passive motion)

In 1998, Tyler et al. proved that the immediate strain after ACL reconstruction lessens the restraining of muscle functions of a knee joint area usually observed in an early postoperative period. This is also proved by the enhanced myoelectrical activity of the vastus medialis oblique (VMO) muscle two weeks following the operation. They also observed that anterior knee pain lessened in patients who were treated with limb strain just after the operation. No differences with respect to knee flexibility, range of motion or functional assessment were noted between patients treated with limb strain and those without it. Possible complications may appear in patients who were treated by autogen BPTB graft [3].

The advantages of the earlier strain are as follows:

- better cartilage nutrition,
- minimizing bone mass loss,
- minimizing arthrofibrosis risk,
- faster recovery of quadriceps femoris muscle function [3].

The modern rehabilitation process is comprehensive and should involve the entire organism of the patient, including cardiovascular system training, proprioception and muscle coordination training, by the appropriate activity selection. The activities should be safe, adjusted to the patients' abilities and interests, but also should contain the elements of a sport discipline a patient would like to return to [3]. The major aim of the modern rehabilitation program is to enable a patient to recover as quickly as possible with respect to daily functioning, work, and sport activity. Such a recovery brings about both mental and economic benefits [2].

MATERIALS AND METHODS

The research group consisted of 18 people (5 women and 13 men, aged from 17 to 46, average age of 24) after ACL reconstruction with ST and GR tendon grafts. All patients were rehabilitated from 2008 to 2009 in the Stefan Bołoczko Motor Rehabili-

tation Center, located in the Olsztyn Higher Education Institution. The rehabilitation protocol described in *Physical Therapy* No. 6, Vol. 87 was employed [8]. After periods of 3 and 6 months, patients underwent isokinetic muscle strength test. The Biodex system 3 Pro was used. The test involved both healthy limbs and those after ACL reconstruction.

After 3 months following reconstruction, the examination was performed at 90––40° for both limbs with speeds of 180°/s and 300°/s. In the 6th month the examination was carried out from 90° to the maximum extension established for each lower limb separately with speeds of 90°/s and 240°/s. If the difference of muscle strength after 3 months for extensor and flexor was within a range of equal to or less than 30%, then the running program was started. After 6 months the repeated test with respect to full motion range was performed. If the difference of muscle strength between the operated and the healthy limb was equal to or less than 15%, the patient was allowed to begin an appropriate sport activity.

The rehabilitation program began in the 1st week following reconstruction. It was divided into 6 stages. Rehabilitation sessions took place 3–5 times a week for 6 months. Activities were adjusted with respect to the patient's needs and abilities [8].

Phase 0: Early Postoperative Phase

Weeks 1–2

Goal: Restoring full passive knee extension and diminishing joint swelling.

Patients are hospitalized from 1 to 3 days. In the period between discharge from hospital and the beginning of the rehabilitation program at the outpatient clinic, patients should follow a home program with the main focus on restoring a full range of motion and diminishing joint swelling. To diminish swelling, the patient is advised to keep the limb elevated and to perform ankle plantarflexion-dorsiflexion exercises (Fig. 2), quadriceps isometric setting and hamstring stretches (cocontraction) (Fig. 3). Crutches can be used to improve gait and to reduce swelling. Full passive knee extension is the most important goal in the 1st week. Gravity is used to restore full knee extension by using two chairs, with the leg elevated on a hard pillow under the heel when sitting or with the leg elevated on the edge of the bed in the supine position (Fig. 2).

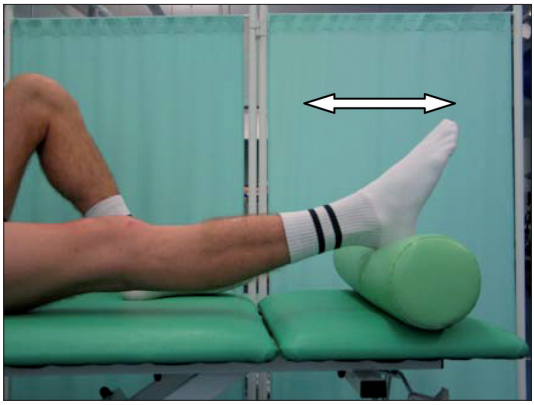

Fig. 2. Passive extension with dorsal and plantar foot flexion

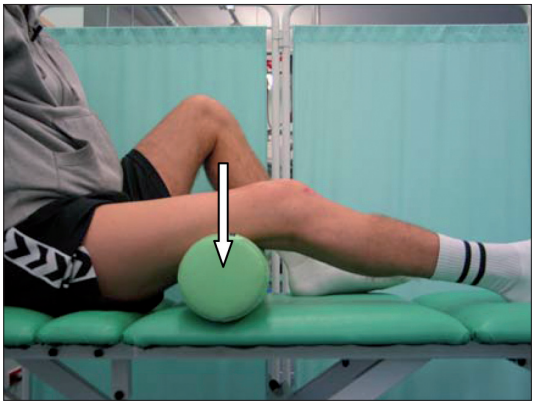

Fig. 3. Cocontraction

Phase 1: Walking Phase

Weeks 2–4

Goals: Achieving normal walking pattern without crutches; controlling balance with both-limb support; controlling balance with single-limb support; controlling dynamic stability of the uninvolved leg. Crutches are used for 2 weeks following reconstruction until the patient's weight is gradually tolerated. The criterion for discontinuing the use of crutches is evidence of no limping. Weight shift exercises are started as early as possible. If full body weight is not tolerated during squatting exercises, counterweights are used to avoid swelling or pain. Cold therapy (glacier packs) is applied for 15 minutes every 3–4 hours and immediately following exercises until swelling diminishes (Fig. 4).

Exercises:

- stationary bicycle to improve range of motion and diminish swelling,
- walking exercises on even surface,
- walking exercises on treadmill to improve gait patterns after discontinuing crutches,
- squats: if the patient has persistent swelling or pain, squatting exercises are performed employing a pulley apparatus with the use of counterweights (Fig. 5),
- gastroc exercises: heel lift exercises,
- single leg stance, starting on uninvolved leg,
- single leg stance, involved leg,
- balance exercises, starting on uninvolved leg,
- lunges: front, front/side, side, rear/side, and rear lunges on uninvolved leg,
- step-up exercises: front, side, rear, starting with uninvolved leg.

Fig. 4. Cold therapy

Fig. 5. Leg press

Phase 2: Balance and Dynamic Joint Stability Phase

Weeks 5–8

Goals: Controlling balance initially with both-limbs support, then with single-limb support, on uneven surface; controlling dynamic stability, both-limbs support; controlling dynamic stability, involved leg; step-up and step-down; squatting, both legs; sideways and backwards walking.

Week 5

Exercises:

- single leg stance, eyes closed,
- single leg standing on balance mat, appropriate knee and hip positions,
- rocker board, Wobble board, both legs (Fig. 6, 7),
- leg balance reach, involved leg,
- arm balance reach, involved leg,
- step-up, both legs.

Fig. 6. Rocker board

Fig. 7. Wobble board

Week 6
Exercises:
- backwards and sideways walking on treadmill,
- wobble board, both legs with weights,
- wobble board, both legs, ball throws,
- wobble board, single leg,
- step-down, uninvolved leg (Fig. 8).

Fig. 8. Step-down on uninvolved leg (steps from the left side: 18 cm, 10 cm and 5 cm high)

Week 7
Exercises:
– single leg stance on trampoline, ball throws,
– step-up and step-down, involved leg, different directions,
– balance exercises on balance mat and wobble board.

Week 8
Exercises:
– lunges with bars/weights,
– single leg stance on trampoline, ball throws, different directions (front, back, and sideways),
– single leg stance on balance mat, ball throws,
– step-up on wobble board.

Phase 3: Muscle Strength Phase
Weeks 9–12
Goal: Increasing muscle strength.
Exercises:
– single leg stance with weights, eyes closed,
– single leg stance on wobble board, eyes closed,
– squats on wobble board,
– squats with weights, improving knee flexion (Fig. 9),
– lunges with weights, enhancing knee flexion,
– step-up with weights, increasing heights and weights.

Fig. 9. Squat with weight

Phase 4: Running Phase

Weeks 13–16

Goals: Starting a running program following positive testing results on Biodex system; controlling jumps, both legs; controlling jumps with turns on trampoline, both legs.

Exercises:

- running on treadmill,
- running or jogging outdoors,
- jump training: both legs, trampoline, increasing knee flexion (Fig.10).

Fig. 10. Two-legged jumps on trampoline

Phase 5: Jumping and hopping Phase

Weeks 17–19

Goals: Running sideways and backwards; controlling two-legged jumps on flat and even surface; controlling hops for distance; controlling jumps on steps.

Exercises:

- running backwards,
- hop for distance,
- jumps: two-legged, 180-degree turns, flat, even surface,
- jumps: stair jumping,
- running: figure-of-eight, stop-turn-run,
- agility drills, slow speed.

Phase 6: Plyometric and Agility Training Phase

Weeks 20–24

Goals: Controlling single leg jumps; controlling vertical jumps; controlling sport-specific activities.

Exercises:

- single leg jumps, trampoline,
- single leg jumps, balance mat,
- single leg jumps (forward, backward, sideways on flat and even surface),
- vertical jumps,
- scissors jumps,
- series of jumps: 6–8 2-legged jumps (Fig. 11); 2-legged jumps down a step, then vertical jump,

Sport-specific tasks are introduced during the agility training depending on the kind of sport the patients may return to.

Fig. 11. Series of jumps

Final testing

About 24 weeks after the beginning of the rehabilitation program, patients underwent final testing to evaluate their capacity to begin sport activities.

The criteria the patients had to accomplish were as follows:

- range of motion equal to that in uninvolved leg,
- completed progressive running program,
- the difference in the muscle strength is equal to or less than 15% (Biodex testing),
- positive results of functional tests:
  - single leg speed jumps (10 m distance),
  - single leg hop for distance,

- squat with 50 kg on Smith machine (number of repetitions),
- single leg speed bench jumps,
- single leg jump on dynamometric platform.

RESULTS

Negative results signify that the operated limb is stronger than the uninvolved one. In the muscle strength test carried out after 3 months, 5 people exhibited a large deficit in extensor strength. It exceeded 30% and resulted in the running program delay and rehabilitation process extension. After 6 months, the difference in extensor muscle strength exceeding 15% was noted in 3 people. After 6 months, 1 person manifested the difference in flexor muscle strength exceeding 15% with a speed of 90°/s and 6 patients with a speed of 240°/s. Average results indicate that muscle strength for all muscle groups was reduced by 10% between the 3rd and the 6th month (Tab. 1).

Tab. 1. Difference in muscle strength after 3 and 6 months following ACL reconstruction [%]

No	Sex	Difference in muscle strength after 3 months (180°/s)		Difference in muscle strength after 3 months (300°/s)		Difference in muscle strength after 6 months (90°/s)		Difference in muscle strength after 6 months (240°/s)	
		extensors	flexors	extensors	flexors	extensors	flexors	extensors	flexors
1.	M	31.3	1.6	44.1	9.2	14.3	-9.2	19.5	5.4
2.	M	11.5	1.2	13.8	15.2	16.9	-9.3	12.8	8.4
3.	W	25.3	10.5	1.5	10.9	10.9	16.8	17.6	16.7
4.	W	17.9	7.4	35.7	17.9	4.4	6.1	3.8	-0.1
5.	W	17.3	16.0	7.0	-5.5	2.7	-5.7	-0.2	-2.4
6.	M	13.6	4.8	16.6	20.4	3.0	1.1	3.3	4.2
7.	M	13.9	2.4	9.0	14.3	11.0	3.4	13.3	12.1
8.	M	7.1	8.7	13.5	22.9	4.1	2.5	-2.3	9.3
9.	M	1.6	8.1	15.3	11.0	2.1	6.0	3.2	-4.7
10.	W	11.3	11.6	14.5	7.8	1.6	-2.5	7.3	6.4
11.	M	7.5	0.1	14.2	15.5	13.7	-10.4	5.3	22.5
12.	M	11.1	22.6	4.2	16.9	-9.9	6.3	-7.6	0.6
13.	M	18.9	6.0	38.8	15.5	-2.5	6.5	4.6	-13.7
14.	W	16.6	25.8	27.1	14.3	5.1	1.5	3.1	20.8
15.	M	34.4	19.6	22.2	12.0	22.8	12.5	24.7	18.3
16.	M	2.5	22.7	8.5	16.0	-6.3	15.0	7.6	16.1
17.	M	6.9	0.8	6.2	12.7	2.0	-1.6	-4.5	23.1
18.	M	27.2	10.9	37.6	0.0	3.5	-11.7	11.7	-9.9
19.	Average	15.3	10.0	18.3	12.6	5.5	1.5	6.8	7.4
20.	SD	9.4	8.2	13.0	6.8	8.2	8.6	8.5	11.0

DISCUSSION

On the basis of conducted research concerning muscle strength on Biodex after 3- and 6-month periods following ACL reconstruction, it can be concluded that early, as well as physician and physiotherapist controlled rehabilitation consisting of the quickest beginning of mobility and gradual straining of the operated limb, does not have a negative influence on ACL graft and does not lead to its weakness. Acting according to the aforementioned protocol eliminates the negative results of immobilization such as: stiffness of the graft, muscle atrophy (especially of the quadriceps femoris muscle) and anterior knee pain, occurring as complications [2]. The possibility of starting the running program after only 3 months, thanks to muscle strength testing performed on Biodex, speeds up patients' recoveries with respect to their daily functioning and physical activities without the risk of graft damage. However, it should be also mentioned that the proposed treatment can be carried out only when a given patient has been properly prepared before ACL reconstruction. Such a preparation usually lasts a few weeks, but following reconstruction it then speeds up a patient's recovery in the first rehabilitation stage and positively affects a patient's psyche. In addition, muscle strength should be used as indicator rather than muscle mass measurement, because thigh sizes of many patients following ACL reconstruction do not become comparable in both legs, even after a year of treatment, whereas muscle strength is comparable to a healthy leg. The strength measurement allows for a more accurate evaluation of a patient's current condition [9].

CONCLUSIONS

1. An early implementation of the Norwegian rehabilitation program speeds up a patient's recovery with respect to normal functioning. It may be achieved by enhancing muscle strength reconstruction.
2. Patients rehabilitated according to the abovementioned program were able to begin a suitable physical activity as early as 6 months following ACL reconstruction.
3. The straining stage began early makes a patient's full recovery quicker and, according to the conducted research, decreases the difference in muscle strength between an operated upon and healthy limb.
4. Rehabilitation based on early and gradual straining diminishes the artrofibrosis risk, as well as bone mass and muscle strength loss.

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