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DEVELOPING AN OBJECTIVE CRITERIA FOR RECOMMENDATIONS TO ATHLETES PRIOR TO A RETURN TO FULL TRAINING FOLLOWING KNEE ACL RECONSTRUCTION

Wojciech Fibiger [A-G]

ARTROMED Orthopedic and Rehabilitation Center, Krakow, Poland
The Podhale State Higher Vocational School in Nowy Targ, Institute of Physiotherapy, Nowy Targ, Poland

Abstract

Objective: To determine the cause of the pain and swelling that occurs after a return to training in athletes following reconstruction of the anterior cruciate ligament.

Methods: The study involved 42 athletes who had undergone reconstruction of the anterior cruciate ligament, and subsequently made themselves known because of the pain and swelling in the operated knee which occurred after returning to intensive training. All athletes completed their post-operative treatment and provided consent to the workouts.

In order to determine the cause of the pain and swelling, medical history, orthopedic and ultrasound exams were conducted followed by isokinetic testing of the knee joints muscle strength at three different velocities (60 °/s,180 °/s, 300 °/s). The minimum criteria for muscle strength prior to a return to training after anterior cruciate ligament reconstruction adopted was: quadriceps strength of 85%; the strength of the knee flexor muscles of the operated joint at 90% or more of contralateral side, and a H/Q ratio of 70% or higher.

Results: All athletes cleared to return to intensive training by a doctor were based on the knee stability tests, the range of movement, assessment of pain and swelling and muscle strength using Lovett test. Objective isokinetic muscle strength testing, proprioceptive exam and functional tests were not performed. However, orthopedic and ultrasound exam were normal for all tested athletes who had a quadriceps muscle isokinetic strength less than 85% and the flexor muscles strength less than 90% of contralateral side, while the H/Q ratio for 60°/s was less than 70%.

Conclusions: The authors recommend that sports medicine professional's should ensure that minimal strength levels of the muscles which stabilize the knee after anterior cruciate ligament reconstruction are confirmed by an objective examination using isokinetic dynamometry as the primary criterion after stability assessments for a safe return to sporting activity. We observed that current practice of sports medicine professionals as their criterion assessments for re-admission to sports activity following ACL reconstruction are; stability of the knee joint, assess the joints range of motion, muscle strength testing using the Lovett test, and evaluate pain and swelling. However systematic tests of isokinetic muscle strength, proprioception examination and functional tests are not performed. It is recommended to educate physicians on fulfillment of the proposed criteria for a safe return to the sport after ACL reconstruction. We also identified that the cause of pain and swelling after intensive training following ACL reconstruction which occurs with no changes in the orthopedic and ultrasound exam is strength weakness in the muscles of the operated knee.

Key words: *reconstruction, anterior cruciate ligament, pain, swelling, muscle strength, return to sport*

Introduction

An injury of the anterior cruciate ligament (ACL) is one of the most common ligamentous injuries of the knee joint. Of these injuries most are found to be totally damaged and reconstructive surgery of the ACL is most commonly performed on a young person under the age of 25, who is either involved in amateur or professional sport [1].

After ACL injury the fundamental questions asked by the athlete and support people (e.g. immediate family and coach) are: when will they return to their professional activity, and why will this process take so long [2]. The answer to such a "simple question" is very difficult and depends on a number of factors which have an impact on the efficiency of treatment, such as the circumstances of the injury, immediate response post injury, the type of surgical procedure and the course of rehabilitation, the current symptoms and clinical type and level of sport and motivation, environmental pressures [3].

After ACL reconstruction 60 to 80% of athletes returns to a different sports activity, but very often the level of their game and the results obtained are lower than prior to injury [4-6]. One of the most common causes of the abandonment of the sports activity or return but only at a lower level is the fear of injury recurrence [4].

It has been assumed that a safe return to sporting activity can occur when: the operated knee is stable and the difference in the anteroposterior movement of the operated knee in relation to the uninvolved leg must be less than 3 mm with the use of KT-1000 device. Furthermore there should be no pain and swelling present in the operated joint, range of motion of the knee is full, thigh circumference difference does not

Table 1. *Criteria for return to sports after ACL reconstruction*

• anteroposterior knee stability KT-1000 side to side difference < 3 mm
• no pain or other symptoms
• no effusion
• ful ROM
• < 2 cm difference in thigh circumference
• isokinetic quadriceps and hamstring muscle strength quadriceps strength 85% or more of contralateral side hamstring strength 90% or more of contralateral side H/Q ratio > 70%
• proprioception 100% compared with contralateral side
• functional testing battery 85% or greater compared with contralateral side

exceed 2 cm in relation to the uninvolved limb, the strength of the quadriceps in an isokinetic test is over 85% and the flexor muscles is more than 90% of the contralateral side, the H/Q ratio is 70% or higher as evaluated with an isokinetic dynamometer, the operated limb proprioception should be the same as the uninvolved leg, and functional tests should be 85% in relation to the uninvolved leg [1,2,7-10]. (Table 1)

Analysis of all the above parameters allows the sports medicine professional to evaluate the function of the knee joint after ACL reconstruction and determine whether the restored degree of physical fitness of the athlete is sufficient to allow them to start sports training safely. If the athlete does not fulfill the criteria, it is recommended that they should not return to training. A safe return to sporting activity in a relatively short period of time after the reconstructive operation is reported to result in a low risk of re-injury of the knee joint including damage to the reconstructed ACL, of approximately 6-13% [11-13]. In contrast a longer period of operation results in a low level of development of osteoarthritis of the knee [14,15].

Tests of the knee joint's muscle strength is one of the important elements for informing sports medicine professionals about the efficiency and progress of the operated leg's rehabilitation, but also a crucial factor determining whether the athlete after ACL reconstruction can return to sports activities and at what level. Lower limb muscle strength can be assessed with a very simple and subjective Lovett test, but also objectively using a dynamometer under static conditions, isometric contractions as well as a dynamically with isotonic or isokinetic contractions. Muscle strength testing using isometric contractions can be safely performed at every stage of treatment even during very early rehabilitation after reconstruction of the ACL. While evaluation of dynamic isokinetic muscle strength of the knee joint following ACL reconstruction in the full range movement at the three velocities 60°/s, 180°/s and 300°/s can be safely performed after the 20th week post surgery. However this has not been systematically investigated to provide us a full view of the effectiveness and impact of the supporting treatment, furthermore it allows you to monitor the progress of treatment, while assisting to determine the type and value of the loads during exercise, as well as complete treatment.

Methods

All athletes who following arthroscopic single-bundle reconstruction of the ACL with semitendinosus and gracilles muscle tendon, and who reported because of pain and swelling of the operated knee which appeared after returning to intensive training were included in the research. The athlete's surgery and rehabilitation treatments were carried out in multiple centers. All athletes prior to the start of the training obtained permission to return to sporting activity from operating surgeon.

The main goal of the research was to identify the cause of the pain and swelling after returning to training. The medical history of each participating athlete was documented. Orthopedic and ultrasound exams were conducted followed by isokinetic muscle strength test of knee joints. Furthermore, athletes were asked about the criteria used by their supervising doctor who ended the treatment and agreed to their return to training. In particular the athletes were asked whether the doctor performed a knee joint stability exam physically or/and with an arthrometer, checked the range of mobility and thigh circumference, checked the muscle strength by performing Lovett's test or/and dynamometer, proprioception exam, functional tests and assessment of pain and swelling.

We examined the dynamic isokinetic muscle strength of the extensor and flexor of the knee joint with EASYTECH device 3 GENU and it was performed in accordance with the manufacturer's standard protocol. Prior to undergoing testing each athlete was instructed in the test, and all physical characteristics data was collected (full name, age, weight, height and dominant side of the body). Athletes also provided the

date of their operation and a clinical examination was performed, including assessment of the stability of the knee joint, range of motion, and the presence of pain and/or swelling. Before commencing the test athletes completed a 10 min warm up with a load of 100 W on an ergometer at a cadence of 70-80/min. The dynamometer was configured individually to each athlete before testing, with the chair and the dynamometer lever tip positioned at the axis of rotation of the knee joint. Pelvis, torso and thighs were stabilized by strips fixed to the seat to eliminate supporting movements.

Before each test a full extension of the knee joint was determined. The starting position was the maximum flexion of the joint. The same isokinetic muscle strength test of the extensor and flexor of both knee joints (operated and uninvolved) was performed at three different velocities (60 °/s, 180 °/s, 300 °/s) with the objective of a more thorough analysis of the strength of the muscles. All testing began with the uninvolved leg.

Before each muscle strength test at a given velocity, 5 repetitions for familiarization were provided at each velocity immediately prior to testing at the designated velocity. Testing consisted of 30 repetitions at 300 °/sec and 5 repetitions for both 180 °/s and 60 °/s. Between the familiarization and the test there was a 30 s rest, and between velocities a 90 s recovery was provide, while between limbs a 5 min recovery was allowed.

At the completion of isokinetic testing each athlete recovered on a cycle ergometer for 10 min with a load of 60W at a cadence of 60/min. Peak values for the extensor muscles and flexor of the knee operated and uninvolved leg were analyzed for all investigated movement velocities. Test results are shown in Nm and as a percentage by comparing the knee (extensor/flexor) muscle strength between the operated and uninvolved considering the muscles of the uninvolved knee joint as 100%. The results also included a percentage value of the flexor (hamstring) to the extensor (quadriceps) - H/Q% ratio at a speed of 60 °/s.

The test was performed to evaluate if the strength of operated knee fulfills minimal criteria allowing a patient to return to trainings. And due to this, statistical analysis was not performed.

The following minimum criteria were specified: the isokinetic strength of the quadriceps a minimum of 85%, and the strength of the flexor muscles of the operated knee more than 90% of contralateral side, H/Q% ratio 70% or higher.

Results

The Study of dynamic muscle strength of the extensor and flexor of the knee isokinetic conditions was conducted in the years 2006-2012 in Orthopedic and Rehabilitation Centre ARTROMED in Krakow and involved 42 athletes (23 women and 19 men) aged 17-29 years practicing sports such as basketball, soccer, volleyball, judo, and table tennis. Detailed characteristics of the test group are given in Table 2.

Table 2. *Characteristics of the study group*

		mean (± SD)
n	study group	42
	women	23
	men	19
Sport (discipline)		
basketball	study group	25
	women	14
	men	11
soccer	study group	6
	men	6
judo	study group	4
	women	2
	men	2
volleyball	study group	4
	women	4
table tennis	study group	3
	women	3
Age (years)	study group	22,19 ± 3,57
	women	22,9 ± 3,9
	men	21,2 ± 2,97
Height (cm)	study group	178,47 ± 7,78
	women	175,13 ± 17,6
	men	182 ± 5,96
Body mass (kg)	study group	72,02 ± 27,57
	women	65,91 ± 9,78
	men	79,42 ± 12,65

All persons tested were characterized by right-hand dominance, with 25 people having their right knee and 17 their left knee operated. The average time elapsed from the date of reconstruction of ACL to the performance of muscle strength test was 6.59 + 1.41 months (females: 6.52 + 1.75 months; males: 6.68 + 0.88 months). Each athlete's return to training by the doctors was based on stability of knee joint, range of movement, assessment of the pain and the swelling and testing muscle strength by Lovett's test. Objective isokinetic muscle strength exam, prioreception exam and functional tests were not performed.

Percentage of the average knee extensor muscles strength of the operated knee was less than 85% of the uninvolved leg at all tested velocities, similarly the average percentage of the knee flexor muscles strength of the operated joint represented less than 90% of the uninvolved knee flexor at velocities of 300 °/ s and 60 °/s. (Table 3 and 4).

The average H/Q ratio measured at a speed of 60°/s for the operated knee joint was higher and amounted to 69.1% (72.8% women; men 64.7%) in comparison with the rate for uninvolved knee of 62.9% (63.3% women; men 62.5%). The average H/Q ratio of the operated leg throughout the cohort was lower than 70% and only in women did it exceeded the established minimum criteria.

Discussion

Medical literature often discusses the problem of returning to the sports activity after ACL reconstruction with various attempts at reporting an objective criterion [1-4,16,17].

The most commonly used criteria to assess the effectiveness of the surgical treatment after reconstruction of a knee ACL is the anteroposterior stability [16,18,19]. Only when this criterion is met, is the rebuilding of strength and muscle mass stabilizing the knee considered. A prerequisite to recovering the adequate strength and muscle mass of the knee is resolving any of pain, and/or swelling, and regaining the full range of motion in extension and flexion of the knee after surgery. The correct mass and muscle strength of knee stability after reconstruction has a decisive influence on the function of the knee and its evaluation using various functional tests and the

Table 3. *The mean value of the peak moment of the extensor and flexor muscle strength knee joints in Nm*

velocity		mean PT of the extensors knee joints in Nm ± SD		
		study group	women	men
300°/s	operated leg	75 ± 24.7	59.2 ± 15.1	94.2 ± 20.1
	univolved leg	96.6 ± 25.4	80.6 ± 20.2	116 ± 15.9
180°/s	operated leg	103.2 ± 30.5	83 ± 16.9	127.5 ± 25
	univolved leg	123.9 ± 30.2	108.7 ± 25.5	142.2 ± 25.3
60°/s	operated leg	158.8 ± 57.5	121.8 ± 33.5	201.5 ± 49.3
	uninvolved leg	209.7 ± 62.6	174.5 ± 41.6	174.5 ± 41.6
		mean PT of the flexors knee joints in Nm ± SD		
300°/s	operated leg	79.3 ± 36.1	58 ± 23.2	105.1 ± 32.1
	uninvolved leg	92.4 ± 37.6	71.7 ± 27.8	117.4 ± 32.9
180°/s	operated leg	93.7 ± 31.4	77.4 ± 24.4	113.4 ± 27.9
	uninvolved leg	102.6 ± 34.6	86.6 ± 25.6	121.9 ± 34.7
60°/s	operated leg	106 ± 33.9	87.7 ± 24.5	121.3 ± 31.1
	uninvolved leg	131.9 ± 39.7	111.1 ± 28.1	155.8 ± 38.1

Table 4. *Percentage of the extensor and flexor muscles strength the operated leg to uninvolved leg*

velocity	% ratio PT operated leg to uninvolved leg	study group	women	men
300°/s	quadriceps	77.3 ± 14.8	74.3 ± 15.3	80.8 ± 13.6
	flexors	85.5 ± 15.9	82.5 ± 17.6	89.2 ± 13
180°/s	quadriceps	82.7 ± 12.8	77,1 ± 11.2	89.4 ± 11.5
	flexors	92 ± 18.6	90.3 ± 19.5	94.2 ± 17.7
60°/s	quadriceps	75.2 ± 15.3	70.2 ± 15.9	80.9 ± 12.8
	flexors	80.4 ± 13.9	78.4 ± 10.7	82.8 ± 16.8

subjective evaluation of the results of treatment by the patient [7,20]. Regaining the stability and proper knee function following cruciate ligament reconstruction during the rehabilitation process takes time and must be tailored to each individual.

Our study of knee extensor and flexor isokinetic muscle strength should become standard and obligatory for sports medicine professionals when deciding on an athlete returning to training after reconstruction of the ACL. Importantly the isokinetic testing should encompass the full-range of velocities characteristic of knee movement while running (300°/s), walking (180°/s) and exercising (60°/s). Furthermore the testing of the extensor and flexor muscle strength of the knee should be conducted through the full range of movement of the knee joint. The sports medicine professional should then compare the obtained muscle strength values of the extensor and flexor from the operated knee with the values of the uninvolved knee at each of the test velocities.

Athletes recruited to participate in this study were all included cleared for training following routine, subjective health assessment, including an assessment of the anteroposterior stability knee range of motion, the presence of pain and swelling. However we identified that as a criterion for safe return to sporting activity does not include testing of knee joint isokinetic muscle strength, this results in the admission of athletes to workouts with weakened strength of the muscles of the operated knee. In the assessed athletes the extensor muscle strength of the operated knee amounted to less than 85%, and the flexor muscles strength less than 90% of the muscle strength of the uninvolved knee, while the ratio of H/Q for movement speed 60 °/s was less than 70%. Indicating that the majority of these athletes did not meet the minimum criteria in muscle strength to stabilize the knee after ACL reconstruction in order to safely return to intense physical activity [1-4,7].

The consequence of weakening in the operated knee's extensor and flexor muscles, which serve a protective function for the transplanted anterior cruciate ligament is pain and swelling after intensive training, which in the tested athletes subsided after these muscles were strengthened. Pain and swelling of the knee joint after reconstruction of an ACL are a typical reaction of the knee to the use of too high a loads in relation to the current (weakened) stability of the knee joint's muscle strength, which is substantially related to re-injury of the knee and in particular damage to the reconstructed ACL. We report that the cause of pain and swelling after a return to intensive exercise after ACL reconstruction with no changes in orthopedic and ultrasound exam, was the weakness of muscle strength of operated knee. We believe that sports medicine professionals are allowing athletes to return to full training too soon after ACL reconstruction.

Conclusions

The authors recommend that sports medicine professional's should ensure that minimal strength levels of the muscles which stabilize the knee after anterior cruciate ligament reconstruction are confirmed by an objective examination using isokinetic dynamometry as the primary criterion after stability assessments for a safe return to sporting activity. We observed that current practice of sports medicine professionals as their criterion assessments for re-admission to sports activity following ACL reconstruction are; stability of the knee joint, assess the joints range of motion, muscle strength testing using the Lovett test, and evaluate pain and swelling. However systematic tests of isokinetic muscle strength, proprioception examination and functional tests are not performed. It is recommended to educate physicians on fulfillment of the proposed criteria for a safe return to the sport after ACL reconstruction. We also identified that the cause of pain and swelling after intensive training following ACL reconstruction which occurs with no changes in the orthopedic and ultrasound exam is strength weakness in the muscles of the operated knee.

Declaration of interest

The author reports no conflict of interests.

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Address for correspondence:
Wojciech Fibiger, MD, Ph
ARTROMED Orthopedic and Rehabilitation Center
Reymonta 22
30-059 Kraków, Poland
Tel. +48-600-631-536
E-mail: fibigerw@artromed.pl