

Evaluation of strength muscle recovery with isokinetic, squat jump and stiffness tests in athletes with ACL reconstruction: a case control study

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Summary. *Background:* The anterior cruciate ligament (ACL) rupture accounting for about 50% of all knee ligament injuries. The rehabilitation program requires a long time to rebuild muscle strength and to reestablish joint mobility and neuromuscular control. The purpose of the study is to evaluate the muscle strength recovery in athletes with ACL reconstruction. *Methods:* We enrolled soccer athletes, with isolated anterior cruciate ligament rupture treated with bone-patellar tendon-bone autograft arthroscopic reconstruction. Each patient was evaluated comparing operated and controlateral limb by isokinetic test and triaxial accelerometer test. Isokinetic movements tested were knee flexion-extension with concentric-concentric contraction. Accelerometer test were Squat Jump Test (SJT) and Stiffness Test (ST). *Results:* 17 subjects were selected, there was no significant difference in isokinetic quadriceps and hamstrings results in strength and endurance values. Parameters of ST were comparable between the operated and unoperated side. In SJT a significant statistical difference was in height of jump ($p=0,02$) no statistical difference was evidenced in the other measures. *Conclusion:* Currently complete recovery of symmetric explosive strength seems to be an important parameter for evaluating the performance after ACL reconstruction and the symmetry in test results jump could be associated with an adequate return to sports. In our study the explosive strength is lower in the limb operated than the healthy one. Explosive strength recovery with plyometric training should be included in the post-surgical rehabilitation protocol and its measurement should be performed to assess the full recovery before the restart of sport activities. (www.actabiomedica.it)

Key words: anterior cruciate ligament rehabilitation, explosive strength, bone patellar tendon bone autograft, muscular recovery

Introduction

The anterior cruciate ligament (ACL) rupture accounting for about 50% of all knee ligament injuries (1,2). ACL injuries often occur during sports activities, that involving jumping, and pivoting. Soccer, football, and skiing have been characterized as higher-risk of ACL injury than other sport activities (3).

Surgical reconstruction of the ligament is a common treatment in athletes with knee instability, who had to restore the physiologic functions of the injured knee (4-7).

ACL reconstructive surgery is typically performed with a bone-patellar tendon-bone (BPTB) or semitendinosus and gracilis tendon (STG) autografts.

The consequent rehabilitation program requires a long time to rebuild muscle strength and to reestablish joint mobility and neuromuscular control (8,9).

To obtain a more complete assessment of function following ACL reconstruction, it has been suggested that should be used functional tests that include muscle strength, power and neuromuscular control (10). A variety of these tests to measure the effectiveness of surgical and rehabilitative interventions have been

described including isokinetic tests, hop tests for distance, timed hop tests, figure-of-eight running tests, vertical jump and squat jump tests (1,11).

Actually there is a lack of standardized objective criteria to accurately assess the ability of a patient to progress through the end stages of rehabilitation and safely return to their previous level of athletic activity after anterior cruciate ligament reconstruction (12). The purpose of our study is to evaluate the strength muscle recovery in athletes who underwent ACL reconstruction with bone-patellar tendon-bone autograft, through the measurement of objective variables in squat jump test, stiffness test and isokinetic test.

The endpoint was to observe possible differences in the isokinetic values, squat jump test data and stiffness test results between the two limbs of each individual (the operated knee compared with the contralateral limb).

Materials and methods

We enrolled football players with isolated anterior cruciate ligament injury treated with arthroscopic reconstruction bone-patellar tendon-bone autograft, one year after the surgery.

The patients had not post-surgical complications and didn't undergo other interventions or injury at the other limb, and performed the same rehabilitation treatment with the same operator.

Participants were informed on the scope and procedures of the study. All individuals provided written informed consent before participating in the study. The Institutional Ethic Review Board of our University Hospital approved the study in accordance with the National Health Council Resolution No. 196/96 and with the Helsinki Declaration of 1975, as revised in 2000.

All patients were evaluated by isokinetic test (BIODEX Medical System®, Shirley, NY, USA) and by squat jump and stiffness test with triaxial accelerometer (Sensorize® Motion Sensing Technology, Rome, Italy).

Isokinetic test were carried out with a precise number of operations in order to reproduce equal conditions in all subjects. Before beginning the test, each patient underwent 5 min of warm-up and 5 repetitions to familiarize with the machine and prevent damage. The movements evaluated were knee flexion-extension

with concentric-concentric contraction. The parameters tested were Peak Torque (measured in Newton/meters) and Average Power (measured in watts).

All patients underwent an isokinetic strength test with 5 repetitions at an angular speed of 90°/s and an isokinetic endurance test with 15 repetitions at an angular speed of 180°/sec. They observed 5 minutes of rest between the two tests.

The flexion-extension test was performed with the patient sitting aligning the axis of rotation of the dynamometer with the knee one.

After 5 minutes by the isokinetic test, was performed accelerometer evaluation. It was applied through a neoprene belt in contact with the skin at the level first sacral vertebra.

All tests were carried out with a single leg starting with healthy one. Between the two jump tests there was 3 minutes interval (Fig. 1).



Figure 1.

Table 1. Population data

Characteristics	Mean	Median	Standard Deviation	Standard error of mean	Interquartile range	Min	Max	Range
Age	26.18	23.00	8.967	2.175	16	18	44	26
Body Mass Index	23.376724	24.251278	2.0028017	0.4857508	2.7350	18.9920	26.2346	7.2426
Height	1.7971	1.7800	0.05034	0.01221	0.09	1.73	1.90	0.17
Weight	75.47	76.00	6.829	1.656	9	60	85	25

Squat jump test (SJT) performed with a single maximal jump, starting position at 45° of knee flexion, landing in vertical position and evaluating height of jump, time of flight, maximum speed, maximum power and concentric work.

Stiffness test (ST) carried out with countermovement jump followed by seven jumps at extended knee and landing after the seventh jump controlling the vertical position without doing further hops. The parameters tested with ST were: maximum height, average height, average time of flight, power of the best jump, average power and average stiffness.

SPSS 20.0 software was used for all analyses. Descriptive statistics of data included mean, standard deviations, standard error of mean, median, interquartile range, min, max and range (Table 1).

The parametric Student's t-test for paired data was used for analysis. P values of less than 0.05 were considered significant.

Results

17 subjects were selected from a sample of 82 soccer players, assessed after ACL reconstruction surgery.

16 refused to participate in the study, 12 were excluded from the study because of past surgery in the other leg and 18 because of the injury of other structures of the leg involved, 19 were excluded because underwent ACL reconstruction with semitendinosus-gracilis graft.

Considering the endpoint there was no significant difference in isokinetic strength results and isokinetic endurance values of quadriceps and hamstrings muscles between injured and uninjured side (Table 2). Bilateral parameters of stiffness test were comparable between the operated and unoperated side (Table 3).

In SJT a significant statistical difference was in height of jump ($p=0,02$) not statistical difference was evidenced in the other measures of this test (Table 4).

Discussion

To successfully participate in sport, athletes may need to achieve a certain level of physical functioning to enable optimal performance of sport-specific tasks (13).

Furthermore return to participation in sport is an important outcome when evaluating the success of an-

Table 2. Isokinetic Test Data

Physical Test	Mean	Standard Deviation	Standard Error	Sig.
Peak torque (N/m) Ext 90°	6,2647059	41,6990399	10,1135027	0,544
Average power (W) Ext 90°	2,8529412	26,0086072	6,3080138	0,657
Peak torque (N/m) Flx 90°	5,7764706	15,9413193	3,8663378	0,155
Average power (W) Flx 90°	7,5764706	14,8485912	3,6013124	0,052
Peak torque (N/m) Ext 180°	4,3882353	19,5401152	4,7391741	0,368
Average power (W) Ext 180°	2,8235294	23,9794842	5,8158792	0,634
Peak torque (N/m) Flx 180°	5,5941176	16,4479281	3,9892085	0,180
Average power (W) Flx 180°	6,5941176	24,4200858	5,9227408	0,282

Table 3. Stiffness Test Data

Physical Test	Mean	Standard Deviation	Standard error of mean	Sig.
Maximum Height	0,0088235	0,0375637	0,0091105	0,347
Average Height	0,00118	0,02934	0,00712	0,871
Average Time of Flight	0,0082353	0,0366120	0,0088797	0,367
Average Power	1,0735294	4,1043178	0,9954433	0,297
Power of the best jump	0,72471	4,55954	1,10585	0,522
Average Stiffness	-0,0023529	0,0508096	0,0123231	0,851

Table 4. Squat Jump Test Data

Physical Test	Mean	Standard deviation	Standard error	Sig.
Maximum Height	0,0241176	0,0276267	0,0067005	0,002
Time of flight	0,0141176	0,0329884	0,0080009	0,097
Maximum Speed	0,05471	0,16485	0,03998	0,190
Maximum Force	0,2941176	2,9933511	0,7259943	0,691
Maximum Power	1,1711765	4,6374776	1,1247535	0,313
Concentric Work	3,6117647	14,4388643	3,5019390	0,318

terior cruciate ligament (ACL) reconstruction surgery. (14)

The majority of athletes who sustain ACL injury do not successfully return to their preinjury sports level (1). Therefore restored lower-limb function is an important factor to minimize the risk of reinjures (15).

Current practice around ACL reconstruction rehabilitation is quite inconsistent due to the lack of clear sequential functional progression aimed at achieving task specific goals. Furthermore the current criteria for return to sport are vague and rely on personal interpretation (16).

If patients want to return to their pre-injury sport level after surgery, the appropriate time point for restart is essential. Currently, no scientifically established time point exists (17).

Moreover there aren't specific tests that are used to assess with certainty the full recovery of an athlete with lesion of LCA (12,18).

Currently complete recovery of symmetric explosive strength seems to be an important parameter for evaluating the performance after ACL reconstruction (19) and the symmetry in test results jump higher of 85% could be associated with an adequate return to sports (20).

In the present study, no significant differences were found in isokinetic peak torque values and aver-

age power data between two limbs showing that the level of muscular quadriceps and hamstrings performance was adequate after one year from injury. Differences in values of stiffness test were also no significant demonstrating a good recovery of muscular elasticity. Regarding squat jump we found a statistical difference in maximum height of jump ($p=0,02$) although other parameters of this test weren't significant.

These results show that the explosive strength is lower in the limb operated than the healthy one despite a full recovery of the peak strength of the quadriceps and hamstrings muscles.

Conclusion

Explosive strength training with plyometric exercises should be included in the post-surgical LCA rehabilitation protocol and its measurement should be performed to assess the full recovery before the restart of sport activities.

The present study presents several limitations that should be acknowledged. It included a small number of participants; several surgeons; no sex differences and early follow-up.

Future studies should include a large sample size; evaluation of patients operated by same surgeon; long

term follow-up and a definition of the best objective parameters for complete recovery after ACL reconstruction.

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