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The effect of progressive eccentric and concentric training on functional performance after autogenous hamstring anterior cruciate ligament reconstruction: a randomized controlled study

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Objective: The aim of this study was to assess the functional results of an early onset progressive eccentric and concentric training in patients with autogen hamstring anterior cruciate ligament (ACL) reconstruction.

Methods: Thirty-three patients with autogenous hamstring ACL reconstruction were randomly divided into study (n=16, mean age; 33.87±8.19) and control (n=17, mean age; 32.64±8.21) groups and followed the same ACL rehabilitation program. Additionally, the study group followed a progressive eccentric and concentric training for 12 weeks on the Monitorized Functional Squat System (MFSS) beginning 3 weeks after surgery. The groups were compared according to the isokinetic strength of the knee extensors and flexors, functional performance (the vertical jump test, a single hop for distance test) and the Lysholm knee scale, the Anterior Cruciate Ligament-Quality of Life Questionnaire (ACL-QOL), before and 16 weeks after the surgery.

Results: The functional outcomes in terms of the vertical jump test (p=0.012), a single hop-for-distance test (p=0.027), the Lysholm knee scale (p=0.002) and the ACL-QOL questionnaire (p=0.000) demonstrated significantly greater improvement in the study group. No significant difference was reported between groups for isokinetic strength of the knee extensors and flexors (p>0.05).

Conclusion: Adding progressive eccentric and concentric exercises to the standard rehabilitation protocol may improve the functional results after ACL reconstruction with autogen hamstring grafts.

Key words: Strength; hop performance; knee function; anterior cruciate ligament injury.

Anterior cruciate ligament (ACL) reconstruction with autogenous hamstring tendons is a common procedure. [1] Usually a 4 to 9 months rehabilitation program of 4 to 9 months is implemented after this surgery. However there is still some controversy about the optimal protocol.

Most of the current rehabilitation protocols focus mostly of functional exercises with low load, and only a few studies analyzed the effects of the strength training. ACL reconstruction.[2-5] It has been shown that even after a satisfactory postoperative rehabilitation resulting in a muscle strength of more than 90% of the non-injured side, the patient with ACL reconstruction may still com-

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plain of a poor function during sportive activities and with their knee related quality of life.[6-9]

Standard rehabilitation programs typically involve concentric and eccentric exercises.[10] We hypothesized that an early onset eccentric and concentric training program with progressive intensity, frequency, and duration ACL reconstruction will improve the functional results after ACL reconstruction.

The aim of this study was to assess the functional outcomes of an early onset progressive eccentric and concentric training in patients with ACL reconstruction with autogen hamstring grafts.

Patients and methods

The study was approved by the local ethical committee. Patients were informed about the study prior to their participation and written informed consent was obtained from all patients.

The study included 33 patients (31 male and 2 female; mean age: 33.24±8.10) who underwent a unilateral arthroscopic ACL reconstruction with autogenous semitendinosus and gracilis tendon grafts, February 2010 and May 2012. Only the patients between 18 and 44 years of age, who had a unilateral ACL tear within the past 40 days to 6 months, and a Tegner activity score of greater than or equal to 4 were included in the study. The patients with concomitant ligament or meniscus injury, previous history of knee surgery were not included. 33 patients with ACL reconstruction were randomly allocated by computer generated random numbers to the study (n=16, mean age; 33.87±8.19) and control (n=17, mean age; 32.64±8.21) groups using the "matched pair" method, matching the patients according to sex, age and body mass index (BMI).

Figure 1 illustrates the randomization process via a Consolidated Standards of Reporting Trials (CONSORT) diagram.

Blinding of the patients to group allocation was maintained throughout the study. However, the physiotherapist was not blinded to group allocation. All patients followed the ACL rehabilitation program that we commonly used in our institution after ACL reconstruction that was based on the studies of Wilk et al. and Majima et al.[11,12]

Weight bearing was allowed as tolerated in the first 3 postoperative weeks. The rehabilitation program was started one week after the reconstruction, and all patients completed a 2 to 3 weeks of acute phase rehabilitation, 3 days a week, that focused on controlling pain and effusion. In the control group closed quadriceps kinetic chain and prone hanging leg extension exercises were performed for range of motion and straight leg raise, iso-

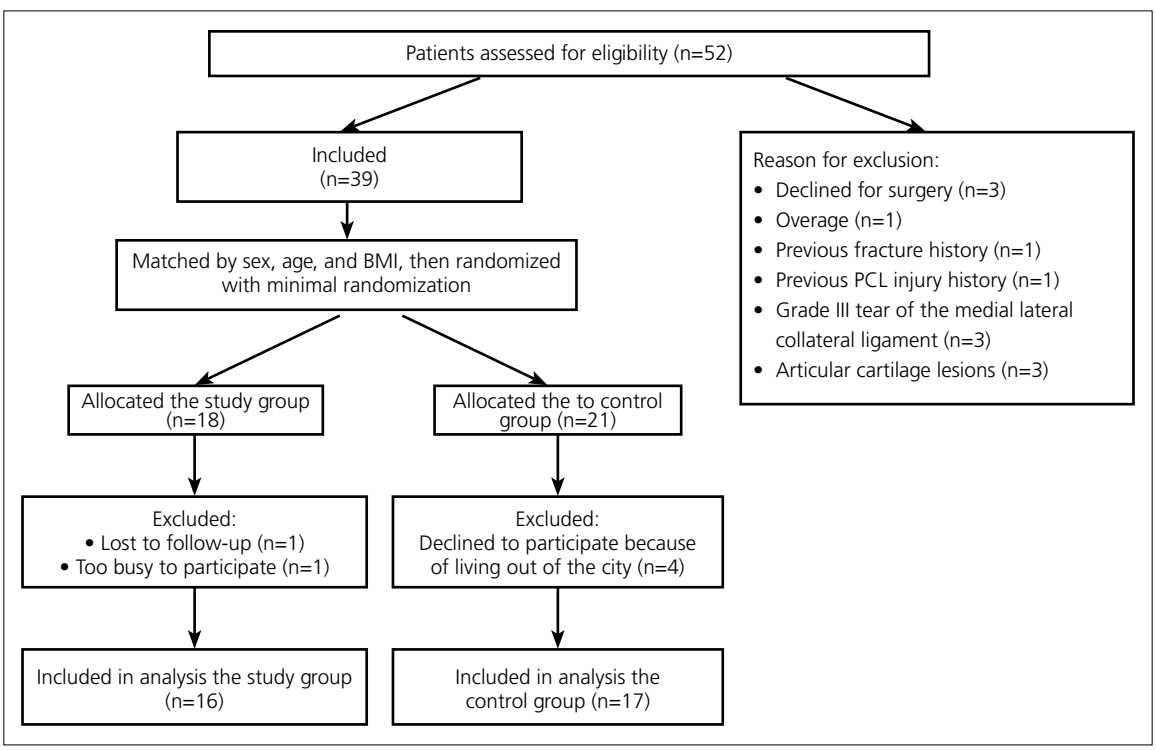

Fig. 1. A consolidated standard of reporting trials (CONSORT) diagram showing patient flow through the course of the study.

metric quadriceps, and hip abduction/adduction exercises to increase quadriceps control. Cycling, theraband strength training, mini squats, coordination and balance exercises were introduced 3-4 weeks after the surgery and resistive range of motion exercises at 6-8 weeks following surgery.

From the 3rd week following ACL reconstruction, patients in the study group continued with the standard ACL rehabilitation protocol and also began a 12week progressive eccentric and concentric training program with a monitored functional squat system (MFSS) (Monitored Rehab System, Haarlem, and The Netherlands) that mimics the movement coordination pattern of a squat jump.[13-18] This system includes special programs for improving and evaluating the concentric and eccentric contraction of quadriceps and hamstring muscle groups during squatting. Patients were instructed to track the trajectory via a cursor shown on a monitor and had to perform coordinated knee flexion and extension using concentric and eccentric muscle contraction (Fig. 2 a-b).

This training program was based upon the American College of Sports Medicine (ACSM) resistance training guidelines.[10]

For progression, 1 repetition maximum (1 RM) method was defined as the weight that can be lifted through a defined range of motion no more than once. Progressive eccentric and concentric training exercise was started with approximately 5% of 1 RM that patients could lift with uninjured leg and progressed every week gradually 50% of 1 RM till 16th postoperative week. The patients were asked to perform 2-3 sets, with 2-3 minutes of recovery between sets. Training was conducted 3 times a week for 12 weeks, with a throughout progressive multiple-joint exercise overload with bilateral eccentric and concentric muscle action in a closed kinetic chain for both extremities.

All patients underwent isokinetic and functional measurements (the vertical jump test, a single hop-for-distance test), the Lysholm knee scale, the Anterior Cruciate Ligament-Quality of Life Questionnaire before and 16 weeks after the surgery. They warmed up by riding a stationary bike for 8 min at 65 rpm and 0.8 watt before performing isokinetic and functional tests. Each patient was asked to perform three trials of hop and jump tests with both limbs and the average scores were used for analysis. The uninvolved leg was tested first followed by the involved leg in all measurements and 2 minutes of rest was inserted between the test series. The limb symmetry index (LSI) was calculated for all isokinetic and functional measurements as per the following formula: (involved leg/uninvolved leg)*100.[19] With this method each value is presented as a proportional deficit (percentage) of the operated compared to the non-operated leg.

The protocol using an isokinetic dynamometer (Isomed 2000®, Gewerbering, Germany) included three submaximal extension/flexion concentric trials followed by three maximal trials with the dynamometer set at 60°/sec. After a 30 sec break three submaximal and three maximal trials at 180°/sec were performed. The maximum torque for knee extension and flexion in each angular velocity (average of three trials) was calculated.

In the vertical jump test, the injured leg was positioned closest to the wall. The patients were standing on both feet, one foot length away from the wall. After bending down to a knee flexion of 80°-90°, they jumped as high as possible vertically and made a mark on the wall with a pen. The participants were instructed to stand and land on both legs. The distance from the floor to the pen marking was measured in cm.[20,21] In single hop-for-distance test the patients stood on the leg to be tested, hopped, and landed on the same limb. The distance hopped, measured at the level of the great toe, was measured and recorded to the nearest centimeter from a standard tape measure that was permanently affixed to the floor.[22,23] Subjects filled the Lysholm knee scale in order to record their patient self-assessment and the An-

Fig. 2. **(a)** Flexion in half squat position. **(b)** Extension in half squat position. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

terior Cruciate Ligament-Quality of Life Questionnaire (ACL-QOL).[24-26]

All data were analyzed using SPSS software (IBM Software, Armonk, NY, USA). Sample size was based on parameter estimation of the reliability coefficient for overall limb symmetry index, with a lower confidence interval (CI) width of 0.1, an expected ICC of at least .85, and a one-tailed CI set to 1-α (α=.05). Using these parameters, the estimated sample size required was 36 subjects. We initially recruited 52 subjects to account for a dropout rate of up to 25%. The data were analyzed with independent sample t-test to compare mean differences in functional outcomes between the groups. The p values less than 0.05 were considered significant.

Results

There was no statistically significant difference between the groups for age, BMI and the timing of surgery (p>0.05) (Table 1). Descriptive data were grouped into three categories: a) the Lysholm knee scale, b) isokinetic variables (peak torque of knee extensors and flexors at 60°/sec and 180°/sec) and c) functional tests (the limb symmetry index for the vertical jump test and the hop test measures) d) the ACL-QOL questionnaire in all groups.

Table 1. Physical characteristics of the patients (mean±SD).

	The study group (n=16)	The control group (n=17)	p*
Age (years)	33.87±8.19	32.64±8.21	n.s.
Body mass index (kg/m^2)	24.50±2.36	24.52±0.94	
Duration of injury (months)	2.93±2.76	3.35±2.95	

*Independent sample t test, n.s. non–significant. SD: Standard Deviation.

Table 2. Comparison of the groups for main outcome measurements (mean±SD) before and after the operation.

Main outcome measurements	The study group (n=16)	The control group (n=17)	p
Lysholm (score 0-100)			
Pre-operation	58.25±13.84	63.29±9.80	0.240
Post-rehabilitation	88.31±3.53	80.76±8.30	0.002*
Knee flexion at 60°/sec (Nm/kg)			
Pre-operation	87.93±37.60	74.30±40.29	0.324
Post- rehabilitation	96.99±32.81	81.19±35.85	0.197
Knee flexion at 180°/sec (Nm/kg)			
Pre-operation	83.10±37.45	73.29±33.31	0.432
Post- rehabilitation	103.89±40.29	86.31±34.35	0.434
Knee extension at 60°/sec (Nm/kg)			
Pre-operation	60.50±26.22	64.61±27.55	0.664
Post- rehabilitation	68.82±26.58	69.54±26.27	0.664
Knee extension at 180°/sec (Nm/kg)			
Pre-operation	58.61±28.22	56.38±27.67	0.820
Post- rehabilitation	77.59±23.28	63.51±28.18	0.127
Single hop LSI (%)			
Pre-operation	76.71±7.8	75.27±9.8	0.644
Post- rehabilitation	91.14±8.6	84.58±7.4	0.027*
Vertical hop LSI (%)			
Pre-operation	60.27±9.5	69.17±23.07	0.157
Post- rehabilitation	89.18±10.36	77.25±14.98	0.012*
ACL-QOL			
Pre-operation	24.28±8.60	36.19±10.92	0.002*
Post- rehabilitation	56.79±1.97	51.95±3.60	0.000*

*Independent sample t test, *p<0.05; LSI: The Limb Symmetry Index, isokinetic and hop variables are for the involved leg, ACL-QOL: Anterior Cruciate Ligament-Quality of Life Questionnaire.

The functional outcomes in terms of the vertical jump test (p=0.012), a single hop-for-distance test (p=0.027), the Lysholm knee scale (p=0.002), the ACL-QOL questionnaire (p=0.000) demonstrated significantly greater improvement in the study group. No significant difference were reported between groups in terms of isokinetic strength of the knee extensors and flexors (p>0.05) (Table 2).

Discussion

Our study showed that the addition of a progressive eccentric and concentric training to the standard ACL rehabilitation program will improve functional outcomes in terms of Lysholm knee scale, the vertical jump test, a single hop-for-distance test and the ACL-QOL questionnaire than the standard ACL rehabilitation program alone except for isokinetic strength of the knee extensors and flexors.

Strength deficit after ACL reconstruction is a common problem seen in previous studies.[27,28] Accordingly, quadriceps weakness is expected in present study regardless of the different rehabilitation programs. It appears that strength deficits in isokinetic measurements depend not only on the population and the methodology but also on the time that has elapsed after the surgical procedure. It is possible that the patients in our study due to bilateral treatment developed more equal side-to-side strength in the early rehabilitation phase; however these functional results become less sensitive in detecting strength deficits in the isokinetic measurement. Furthermore, isokinetic devices' role as assessment tools may not be completely replaced by functional tests in those patients in need of an accurate assessment of strength deficit.

The restoration of the muscle strength, which may be shown with the activities such as one-legged jumping ability is considered to be an important determinant for a successful return to previous physical activity level after ACL reconstruction.[29-31] Fitzgerald et al. suggested that hopping may be used as an evaluation test to show the effect of the treatment.[32] LSI has been the most frequently reported criterion for comparing muscle strength and hop performance with the normal side.[7] Supporting the literature, as in the current study, LSI for a single hop-for-distance and the vertical jump test results revealed functional gains in both groups. However, for the study group, a significant improvement in vertical jump test and a single hop for distance test was achieved compared to the standard ACL rehabilitation alone. The Lysholm knee scale increased from 61% at the initial measurement to 84% at the final measurement (average for both groups). The ACL-QOL scores also significantly improved in both groups. In addition, our results seem to support the previous studies' results that both training programs produced statistical significance on functional outcomes.[33-37]

This trial does have some shortcomings. The number of study participants was small, and the drop-out rate was relatively high. Due to small sample size accompanying with higher standard deviation values may have increased the possibility of having insufficient power to detect muscle strength differences between groups. Second, due to the nature of intervention, it was not possible to blind the physiotherapist to group allocation. One can argue that there is no need for new rehabilitation protocols after ACL reconstruction. Many studies have shown that not all patients return to their previous activity level and do not gain back their lower extremity muscle strength.[33-37] This may suggest the importance of improving other factors such as functional performance early after ACL reconstruction. The present study showed that the addition of the Monitored Functional Squat System to the standard rehabilitation program enabled to get superior functional results than a standard rehabilitation alone. Overall these findings clearly emphasize the importance of progressive eccentric and concentric resistance training during the early rehabilitation stages following ACL reconstruction and can be a viable option as a part of a comprehensive rehabilitation program.

In conclusion, adding a progressive eccentric and concentric exercise program to the standard rehabilitation may improve the functional results after ACL reconstruction with autogenous hamstring grafts.

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