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The outcomes of anterior cruciate ligament reconstructed and rehabilitated knees versus healthy knees: a functional comparison

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Objective: In this study, we aimed to evaluate and compare the functional performance and muscle strength of cases of ACL reconstruction using bone-patellar tendon-bone graft followed by rehabilitation with those of healthy subjects.

Methods: This study included fifteen patients (range: 20 to 35 years) who underwent ACL reconstruction 18 to 24 months previously and a control group of 15 healthy volunteers with similar characteristics. Cases were evaluated with physical examinations, functional tests, subjective scales (Lysholm, Hospital for Special Surgery Knee Score (HSSS), and Tegner activity scale) and isokinetic test. Differences between the reconstruction group and control group were analyzed.

Results: Significant differences were found in the activity level of the reconstruction group ($p<0.05$) and in the clinical findings of the subjects with involved and uninvolved legs ($p<0.05$). When the reconstructed and control groups were compared according to the limb symmetry index, there were significant differences in single-leg hop test, timed hop test, shuttle run and stair hop test ($p<0.05$). The study also revealed a significant correlation between the vertical hop and quadriceps strength in the isokinetic test ($r=0.56$). When the operated knees were compared to the healthy side, mean limb symmetry index was over 92% (with two cases at 88%). When the dominant leg was compared to the non-dominant leg in the control group, the mean limb symmetry index was over 95%.

Conclusion: Functional outcomes similar to those of healthy legs can be achieved following ACL reconstruction with bone-patellar tendon-bone grafting and rehabilitation. The similar functional test results of the operated and healthy subjects prove the effectiveness of the rehabilitation program.

Key words: Anterior cruciate ligament; functional rehabilitation; functional tests; isokinetic test.

Sports injuries have become a current issue due to the increasing interest in recreational activities, the increase in athletes' physical strength and the common disregard for preventive methods. The anterior cruciate ligament (ACL) is the most frequently injured ligament in the knee joint and is the focus of surgical and rehabilitation protocol development.[1] The success of the ACL reconstruction is affected by several factors, including graft selection tension and fixation and applied rehabilitation program.[2] The surgical techniques used in ACL reconstruction vary depending on the type of grafting. The commonly used bone-patel-

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lar tendon-bone graft reconstructions have been considered as the gold standard in ACL reconstruction.[3-5]

The patellar tendon is capable of bearing a force of 2,790±629 N, and the ACL 2,160±629 N.[4] However, some of this endurance is lost during ligamentization. Patellar-tendon strength after fixation with interference screws and reconstruction has been found to be 416±66 N. These values are 20 to 30% that of the intact ACL and show the importance of rehabilitation in knee stabilization following reconstruction.[1,4,6]

Recently, easy to use, economic and short functional tests are available for postoperative assessment.[6-9] Functional tests allow for evaluation of knee performance under simulated daily activities, the isokinetic tests measure muscle strength[10,11] and subjective scales allow for a patient-based evaluation.[12-14] Noyes et al.[15] reported that a controlled landing after a hop is a positive sign of functional performance and defined the symmetry index by examining the functions of both legs. According to this index, if the difference between two legs is more than 15%, functional performance is considered abnormal for the single leg hop test. Normal performance is defined as an index of greater than 85%.

Graft healing, remodeling, adaption and final endurance may take up to 12 months following ACL reconstruction.

In this study, we aimed to compare the functional performance and muscle strength of knees with ACL reconstruction with both the healthy legs and those of a control group.

Patients and methods

Fifteen patients (age range: 20 to 35 years) who attended a rehabilitation program following ACL reconstruction at the Sports Health Clinic between 18 and 24 months prior to this study were included. A second group of 15 males of similar age with no systematic disease comprised the control group. Descriptive data are shown in Table 1.

Table 1. Descriptive findings and comparison results of the cases.

Parameters	Surgery group X±SD (n=15)	Control group X±SD (n=15)	U	p
Age (year)	29.6±5.9	27.0±6.2	83.0	0.22
Height (cm)	176.4±8.3	176.7±6.9	104.5	0.74
Body weight (kg)	77.7±10.3	76.7±5.7	94.0	0.44
Tegner activity scale	6.8±0.4	6.7±0.5	103.0	0.72

Cases were given our clinic's routine ACL rehabilitation program postoperatively and were evaluated using the ACL evaluation form prepared by the authors (*see* Appendix). Information on the nature of the work and measurement methodologies was given and written consent form was signed showing voluntary participation. The study was approved by the ethical committee of the University.

The length between the spina iliaca anterior superior (SIAS) and the medial malleolus in both legs was measured in centimeters in supine position and recorded.[15]

Degree of knee flexion and extension was measured with a goniometer with the subject lying face down (Fig. 1).[15]

The Q angle between the SIAS-mid-patella and mid-patella-tibia tubercle was measured using a goniometer in the supine with the leg in neutral.[15]

The peripheral of the knee was measured 20 cm above and 5 cm below the tibial plateau.[15]

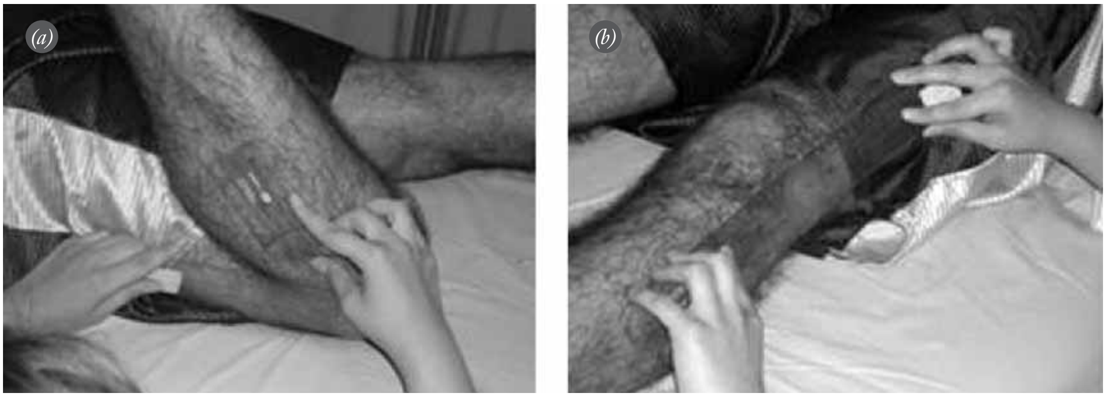

Fig. 1. Measuring the **(a)** flexion and **(b)** extension angle of the knee.

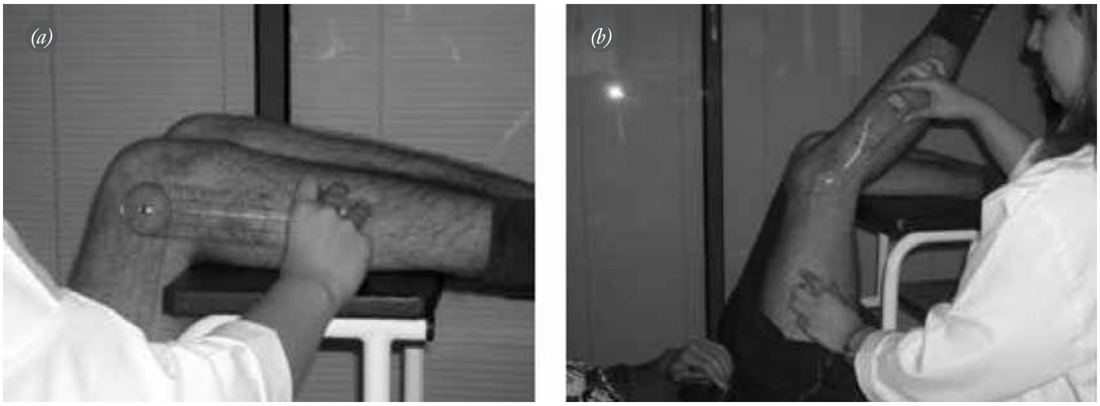

Fig. 2. **(a)** Start and **(b)** end positions in hamstring tightness.

The knee was extended in the supine position and the limited extension was recorded to assess hamstring tension (Fig. 2).[15]

Subjects were given light jogging and stretching exercises for warm-up for 5 minutes. Each test was performed twice and the mean of the results were recorded.[16-21]

The single-leg hop test started standing on a single leg with hands set on the waist. Then, the cases were asked to jump off the horizontal plane and land as far as they could on the same leg (Fig. 3a). The starting and the finishing points of the jump were recorded in centimeters with a measuring tape fixed on the floor.[18]

In the timed single-leg hop test, subjects were asked to jump forward continuously along a 6-meter distance and the time was recorded in seconds using a chronometer.[18]

In the single-leg triple hop test, the subject was asked to jump forward three times consecutively as fast and far as possible while standing on one leg. Total distance was measured in centimeters.[18,21]

In the triple crossover hop test, the subject was instructed to jump over and cross a 6-meter long, 15-cm wide stripe on the ground three times consecutively. Total distance was measured in centimeters (Fig. 3b).[18,21]

The cases were marked on the wall with a stable measuring tape while stretching their arms to the fullest in the vertical hop test. Then, the jump was made and the distance between the two points was measured and recorded.[18,21]

In the shuttle run-1 test, the starting and finishing points were marked with a cone on a 6-meter long distance. Subjects were asked to run from the starting point, go around the cone at the finish point and return to the start as fast as possible. Total was noted with a chronometer and recorded in seconds.[18]

In the shuttle run-2 test, the cases were asked to run toward the finishing point at 6 meters distance as fast as they could, slow down right before the finish line, make a sudden stop and turn, and run back to the starting point. The time elapsed as measured and recorded in seconds.[18]

A 10-meter-long distance was defined and a cone was placed at the start and finish points in the 8-shaped running test. Subjects were asked to run around the cones in a figure 8 as fast as possible. Total time was measured with a chronometer and recorded in seconds.[15]

In the side run test, subjects were asked to run a 12-meter-long distance sideways without crossing their legs, turn 180 degrees and return to the starting point. Time was measured and recorded.[15]

Fig. 3. **(a)** Single-leg hop test. **(b)** Crossover hop test.

In the carioca test, the cases progressed to the finish point at 12 meters sideways by crossing their legs and returned to the starting point in the same manner. Time was measured and recorded (Fig. 4).[15]

In the climbing up/down stairs test, subjects were asked to climb up and down 10 steps as fast as possible. Time was measured and recorded.[15,18]

In the slope up/down test, cases were asked to climb up a 10-meter-long slope, turn 180 degrees around and return. Time from the start to finish was measured with a chronometer and recorded.[15,18]

In the step hop test, subjects were asked to jump on each of a 10-step ladder on a single leg and return. Time was measured and recorded.[15]

In all tests, the leg symmetry index (LSI) was calculated to assess the difference between the two legs. In the functional tests where the distance was measured; LSI: (affected leg / healthy leg) *100 formula was used, and in the functional tests where the time was measured; LSI: (healthy leg / affected leg) *100 formula was used.[22-24]

The knee measurement index (KMI) measured 15 cm above the medial side of the knee joint and calculated using the following formula to assess femoral atrophy: KMI: (affected leg / healthy leg) *100.[11]

Isokinetic tests were performed using a Cybex 6000 isokinetic dynamometer (Cybex International, Inc., Medway, MA, USA) following a 5-minute warm-up exercise. The test was repeated 5 times at 60 degrees and 10 times at 180 degrees.[11,24]

Subjects completed the Hospital for Special Knee Score (HSSS, and Lysholm and Tegner activity scales independently.[14] Score range for the HSSS was 0 to 100 points.[14] The Tegner activity scale in the surgery group was evaluated in preoperative and postoperative categories; with scores ranging from 0 (those who quit

Fig. 4. The carioca test.

activities due to injury or retirement) to 10 (those who completed the activities properly).[12] The highest Lysholm scale score was 100. Points less than 68 were classified as weak, 68-77 as fair, 77-90 as good, and 90 and greater as perfect.[25]

Statistical analysis was conducted using SPSS for Windows v11 (SPSS Inc., Chicago, IL, USA) software. Mann-Whitney U test was used to assess the difference between groups. The relation between functional tests, clinic evaluations, subjective scores and isokinetic test findings was evaluated using the Spearman correlation coefficient. The significance level was set at p<0.05.

Results

Subjects were evaluated at an average of 20±3.1 months following ACL reconstruction. The right leg was dominant in 14 (93.3%) cases in the surgery group and 13 (86.7%) cases in the control group. Seven reconstructions were performed on the right leg and 8 on the left. The lower extremity length, angular flexion value, the Q angle, knee measurement and hamstring tightness of the cases are shown in Table 2.

Table 2. Clinical findings of the cases (p<0.05).

Clinical findings	Surgery group X±SD Affected/Healthy (n=15)		Control group X±SD Dominant/Non-dominant (n=15)	
Lower extremity length (cm)	90.9±5.2	90.9±5.1	91.1±4.6	90.9±4.5
Flexion (°)	132.4±6.7	133.9±4.6	136.7±4.4	136.7±4.4
Q angle (°)	9.1±1.9	9.2±1.9	9.7±1.4	10.1±1.4
Knee measurement (cm)	47.2±2.7	48.2±3.2	46.6±3.1	46.1±3.2
Hamstring tightness (°)	10.7±9.0	10.9±10.1	13.3±9.2	15.5±10.1

Table 3. Functional test results for surgery and control groups (p<0.05).

Functional tests	Surgery group X±SD Affected/Healthy		Control group X±SD Dominant/Non-dominant	
Single-leg hop (cm)	133.2±25.0	151.4±25.3	177.4±11.8	170.2±22.3
Single-leg hop (sec)	2.26 ±0.5	2.08 ±0.3	2.0 ±0.3	1.9 ±0.2
Triple hop (cm)	403 ±96.1	430.6±84.6	502.8±52.4	488.9±68.7
Crossover hop (cm)	358.4±87.1	387.5±82.4	429.8±54.3	431.2±58.3
Vertical hop (cm)	21.1 ±5.0	22.9 ±5.5	24.0 ±5.4	23.7 ±5.6
Shuttle run-1 (sec)	4.6 ±0.4	4.4 ±0.5	4.6 ±0.5	4.7 ±0.5
Shuttle run-2 (sec)	4.5 ±0.8	4.4 ±0.7	4.3 ±0.9	4.5 ±0.6
8-shaped running (sec)	5.2 ±0.4	5.1 ±0.5	5.1 ±0.5	5.2 ±0.6
Side run (sec)	8.8 ±1.8	8.5 ±1.4	7.6 ±0.9	7.7 ±0.8
Carioca (sec)	9.4 ±2.1	9.2 ±2.1	7.6 ±1.3	7.9 ±1.3
Slope (sec)	11.1 ±1.0	10.8 ±0.9	10.6 ±0.5	10.9 ±0.4
Step (sec)	11.9 ±4.2	10.3 ±1.9	8.9 ±0.5	9.2 ±0.6
Stairs (sec)	5.0 ±0.8		4.8 ±0.3	

In the surgery group, the performance of the healthy leg was found greater than the affected leg in the majority of tests (Table 3).

In the surgery group, all cases received LSI scores of 85 and above in the 8-shaped running, side run, and shuttle run-2 tests. In the single-leg hop and step hop tests, 4 cases received a score below 85. Two cases in step hop test received 58.62 and 66.33 points, respectively. The difference between the surgery group and the control group in the single-leg hop, the timed single-leg hop, the shuttle run-2, and step hop tests, was significant (Table 4). Significant differences in the single-leg hop test (in which the distance was measured), triple hop, carioca and step hop tests between the healthy leg of the surgery group and the dominant leg in the control group (Table 5).

The preoperative and postoperative Tegner activity scores in the surgery group were 6.8±0.4 and 4.6±1.5, respectively. The lowest HSSS score was 88 and Lysholm scale was 81 (Table 6). Isokinetic test showed no significant difference between the affected and healthy leg in the surgery group (Table 7). A significant correlation was found between the vertical jump,

Table 4. LSI values of the surgery and control groups.

Functional tests (%)	Surgery group X±SD	Control group X±SD	U	p
Single-leg hop (cm)	88.1±8.4	95.7 ±8.5	54.0	0.015*
Single-leg hop (sec)	93.3±12.3	100.9±7.3	63.0	0.040*
Triple hop (cm)	93.1±10.7	97.0 ±6.2	82.0	0.206
Crossover hop (cm)	92.3±8.2	97.0 ±6.2	74.0	0.110
Vertical hop (cm)	92.9±10.1	98.5 ±7.5	74.5	0.115
Shuttle run-1 (sec)	96.7±6.1	97.7 ±4.9	108.0	0.852
Shuttle run-2 (sec)	97.9±3.3	95.5 ±2.5	60.0	0.029*
8-shaped running (sec)	99.1±4.4	98.2 ±3.4	97.0	0.520
Side run (sec)	97.1±5.1	98.6 ±3.2	86.0	0.272
Carioca (sec)	98.7±8.4	96.4 ±4.6	88.0	0.310
Slope (sec)	96.8±2.9	97.3 ±2.5	102.0	0.663
Step (sec)	88.9±13.2	97.8 ±3.6	53.0	0.014*

*p<0.05

Table 5. Subjective test results of the surgery and control groups.

Subjective tests	Surgery group X±SD Before/After		Control group X±SD
Tegner	6.8±0.4	4.6±1.5	6.7±0.5
Lysholm		95.3±5.7	100.0
HSSS		94.0±3.6	50.0

Table 6. Peak torque values and comparison statistics in the isokinetic tests.

Isokinetic test	Affected leg X±SD	Healthy leg X±SD	U	p
60°/sec flexion	89.0±27.2	89.7±26.3	110.5	0.934
180°/sec flexion	67.8±17.2	67.2±15.2	111.0	0.950
60°/sec extension	126.1±39.5	128.5±40.9	111.5	0.967
180°/sec extension	83.1±24.3	86.2±22.4	103.5	0.709

Table 7. Correlation results between functional and subjective tests in the surgery group.

	Single (cm)	Triple	Crossover	Step	Vertical	Shuttle-2	Stairs	Lysholm
Lysholm	0.56*	0.55*	0.66*	0.62*	0.08	0.02	0.25	1
Tegner	0.13	0.08	0.28	0.37	0.15	0.57*	0.70	0.33

*p<0.05

climbing up/down stairs, and shuttle run-2 tests on the Tegner activity scale (Table 8).

Correlation between the subjective tests showed that a significant correlation between the HSSS and the Lysholm scores (r=0.84); between the Tegner activity scale and flexion isokinetic test with 180°/sec (r=0.52); and between the Q angle and the step hop test (r=0.58). In addition, there was a positive correlation between the vertical hop and the extension isokinetic test done at 60°/sec (r=0.56); the 8-shaped running with flexion isokinetic test done at 60°/sec (r=0.53); climbing up/down stairs and the flexion isokinetic test done with 60°/sec (r=0.66) and the extension isokinetic test with 60°/sec (r=0.56); and the femoral atrophy and the side hopping test (r=0.74).

Discussion

In this study on patients undergoing a rehabilitation program following ACL reconstruction, results were in favor of the healthy leg but there was no difference in muscular strength. There was also no difference between the functional performance and subjective tests evaluations of the surgery and the control group.

There was a relation between the Q angle and flexion and extension with 180°/sec. The current study shows a significant correlation between the crossover hop test in the surgery group and the carioca test in the control group with knee measurement. However, Risberg and Ekeland's study did not reveal a similar relationship between knee measurement and strength.[18] In their study of reconstruction patients with 5 to 9 years of follow-up, Järvelä et al. pointed out a significant correlation between the knee measurement and isokinetic test and reported the method as a convenient and reliable one.[21] On the other hand, Moisala et al. stated that the technique was not sufficient to measure the muscle strength and functional scales were necessary for this purpose.[26]

The LSI was developed by Noyes et al. to evaluate the difference between two legs in functional tests.[15] Noyes et al. pointed out that performance failure can be triggered by many factors such as strength deficiency, pain, psychological problems and found the LSI in the normal population to be above 85%, regardless of the dominant side, sport activity level and gender.[9] In our study, LSI evaluation in the control group was above 85%. Noyes et al. also revealed that the LSI was within abnormal limits in 52% and 49% of the cases who suffered from insufficient ACL reconstruction, in timed single-leg hop and distance-measured single-leg hope tests, respectively. When a single hop test was performed, 50% of the cases showed abnormal performance whereas the rate was 62% when two different functional tests were performed.[9] For this reason, researchers suggest the use of at least two functional tests while evaluating knee performance of the knee. Several studies are available that share the same view.[17,26,27]

The LSI results in our surgery group were above 85%. Subjects were 88% successful in the single-leg hop and step hop tests, and above 92% in the other tests. The reason for such high percentages may be

Table 8. Correlation results between functional and subjective tests in the surgery group.

	Single (cm)	Single (sec)	Triple	Crossover	Carioca	Step	Slope
Single (cm)	1						
Single (sec)	0.08	1					
Triple	0.84*	0.10	1				
Crossover	0.56*	0.28	0.76*	1			
Carioca	0.38	0.59*	0.24	0.10	1		
Step	0.41	0.26	0.43	0.54*	0.14	1	
Slope	0.96	0.47	0.19	0.14	0.66*	0.18	1

*p<0.05

explained by the functional rehabilitation taken after reconstruction. The functional tests are a modified type of sport activities. Exercises during functional rehabilitation are an adapted type of the subjects' regular activities, including jogging, jumping and sprints. Hopper et al.[14] used the 6-meter timed hop, crossover hop, step hop and vertical hop tests in evaluating the functional status of the patients at the one-year follow-up. LSI scores of the above mentioned tests were 94.7%, 90.7%, 95.5%, and 89.4%, respectively. Bach et al. found single-leg hop test LSIs of 91% in their study at 24 months.[6] In another study conducted at the one-year follow-up, the LSI for the triple hop test was reported as 96%, and 91.4% for the step hop test.[28] A study conducted at the two-year follow-up found the LSI for the vertical hop, single-leg hop and triple hop tests as 74.9%, 88.4 %, and 89.5%, respectively.[24]

Goh and Boyle implemented the timed single-leg hop, crossover hop and step hop tests in their study 2 to 4 years following ACL reconstruction to evaluate the condition and performance of the knee and its relation with subjective tests.[29] Tegner et al. utilized the single-leg hop, 8-shaped running, climbing up/down stairs, and slope up/down tests to assess the functional integrity of the knee.[20] Isokinetic tests are done using the open kinetic chain system with no weight transfer. Studies show that isokinetic test has no damage on the graft after the 6th postoperative month.[11]

In a study of patients evaluated up to 6 months following reconstruction, no improvement was observed in the single-leg hop test whereas a significant improvement was noticed in the shuttle run, carioca and the side run tests which require agility. The LSI following surgery in single-leg hop test was recorded as 83%.

In Tegner et al.'s work, 12% of cases succeeded in both the 8-shaped running and slope up/down tests with a quadriceps force of 30°/sec.[20] In our study, 86.6% and 80% of cases succeeded in the 8-shaped running and slope up/down tests with a 60°/sec and 180°/sec quadriceps force, respectively. These high values are in contrast with Tegner et al.'s findings, meaning other tests should be considered. The success rate of the vertical hop and single-leg hop with 60°/sec quadriceps muscle force was 53%, and the single-leg hop and step hop with 60°/sec quadriceps muscle force was 47%. The 8-shaped running and slope up/down tests are mostly used to evaluate daily activities, as stated by Risberg et al.[7] The step hop test was described by all subjects as more challenging than the other tests. The success rates of 53% and 47% might be related to the difficulty of the step hop test. Tegner et al.'s evaluations were performed right after injury while ours were late term evaluations following reconstruction.

The LSI of the cases in the ACL failure and control groups were 32% and 98% in the 8-shaped running test, 58% and 97% in the step hop test, 56% and 95% for the side run test, and 58% and 98% for the single-leg hop test, respectively. Itoh et al. stated that due to the cut-off at the turning point, the 8-shaped running test should be evaluated in the activities regarding sports.[23] Lopresti et al. supported these findings as they found a significant difference between the affected leg and the healthy leg, between the affected leg and the control group, and between the healthy leg and the control group in their study performed 16±9 months after injury. The difference in favor of the control group may root from the fact that proprioception sense in the healthy leg might have been affected after injury in the surgery group.

In their follow-up study at an average of 37 (range: 27 to 51) months after reconstruction, Bach et al. recorded the LSI as 88% for the single-leg hop, 87% for the vertical hop and 90% for the timed single-leg hop tests and found no significant correlation among the functional tests.[6]

We noticed a decrease in the level of activity after surgery despite average LSIs of above 90% and the absence of significant difference with the control group in isokinetic tests. Bearing in mind that the subjective scores were high, it is sensible to think the decrease in the level of activities can be explained with the cases' fear of re-injury. The exercises done before the surgery mostly include turning, cutting off and lateral movements. As our patients were injured doing such exercises, this may create more mental difficult in returning to prior levels of activity. Furthermore, patients tend to select less risky sports or use the affected leg less while doing sports. The Lysholm score was recorded as 90 in the one-year follow-up.

The lack of difference between the two legs in terms of strength and endurance might be related to the postoperative functional rehabilitation program. Quadriceps strength deficiency appears in later ages and it is thought to be a triggering factor for the degenerative changes in the knee joint.[30] Pınar mentioned about his concern about the rate of return to sport activities (as low as 59%) and questioned the probability of reconstruction in protecting the knee from possible future arthrosis.[31]

In our study, a significant correlation was found between the hamstring muscle strength and age. In De Jong et al.'s study, mean quadriceps muscle strength deficiency rate was 14% at 120°/sec, 180°/sec, 240°/sec and 300°/sec and the mean hamstring muscle strength deficiency rate was 4% following ACL injury.[19] In Holm et al.'s[24] study, muscle strength was evaluated at the 6th, 12th and 24th months. The authors observed a significant difference in quadriceps muscle strength in the affected leg at 60°/sec, between the 6th and 12th months. The difference between the 12th and the 24th months was less than the difference between the 6th and the 12th months. In this study, subjects were examined in later stages and no significant difference between muscle strength was found. This lack of difference between muscle strengths may be explained by the functional rehabilitation program and a continuation in participating in sports.

In the surgery group, we found a significant correlation between the single-leg hop and triple hop (0.84), between the single-leg hop and crossover hop (0.56), between the crossover hop and triple hop (0.76), between the timed single-leg hop and carioca (0.59), between the step hop and crossover hop (0.54) and between the slope up/down and carioca tests (0.66). The correlation between the single-leg hop and the other tests may be due to the similar nature of the tests. Risberg and Ekeland[18] found high correlations between the 8-shaped running and climbing up/down stairs (0.74), between the triple hop and 8-shaped running (0.64) and between the triple hop and step hop tests (0.61). They highlighted the necessity of classifying functional tests as either 'daily life' (8-shaped running and stairs) or 'strength/stability' (single-leg hop and step hop) evaluation tests.

There are several studies depicting the relationship between muscle strength and functional tests.[15,23,29] In this study, muscle strength (in 60°/sec extension) and vertical hop were significantly correlated (r=0.56). When the correlation between the functional tests and quadriceps strength is considered, the highest was between quadriceps strength and the triple hop test in 60°/sec. A significant relation between the isokinetic tests and the vertical hop, between the 8-shaped running and climbing up/down stairs tests was also found. During the hop-related functional tests, co-contraction emerges in the muscles around the knee. The role of the extensor muscles in the stability of the knee joint and dynamic agonist position of the hamstring muscles against the ACL can explain the correlation between the isokinetic and functional tests. Escamilla et al. stated that an increase in muscle strength may be possible through exercises squatting against a wall (as a closed kinetic exercise) and single-leg squatting (as an open kinetic exercise) during ACL rehabilitation.[32] Järvelä et al. showed a significant relationship between femoral atrophy and quadriceps muscle strength deficiency and between the single-leg hop and quadriceps muscle strength, in their follow-up study of 5 to 9 years.[21]

Orthopedic and rehabilitation results must be evaluated and measured to approve clinical implementations. Convenient, short-term, valid, reliable tests must be used. Functional tests are useful in determining the criteria for progress, evaluating the feasibility of a return to daily activities and/or sports and in preventing injuries.

We experienced some difficulties in obtaining an isokinetic test appliance, being dependent on another person and frequent equipment dysfunction. The use of more convenient, economic and less time consuming functional tests in the evaluation of results following surgery and rehabilitation is recommended. Thirteen functional tests were used in this study, extending the length of evaluation. For this reason, the single-leg or triple hop, carioca, step hop, and shuttle running test to measure agility and the 8-shaped running and climbing up/down stairs tests to evaluate daily life activities can be used.

In conclusion, functional tests can be conducted simply by physiotherapists and are helpful in returning to sports after rehabilitation. The similarity of our results of the functional test results between the control and surgery groups show the importance of a rehabilitation program. Functional rehabilitation must be taken into consideration to allow for recovery to pre-injury status with no complexity and long-term functionality. In addition, subjects' low level of activity despite high scores point to post-injury anxiety and evaluation of proprioception should be considered.

Conflicts of Interest: No conflicts declared.

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Appendix. Rehabilitation protocol using bone-patellar tendon-bone autograft after ACL reconstruction.

	Week 1	Weeks 2-4	Weeks 5-8	Month 3	Months 4-6	Months 6-12
Functional progress criteria	- Maximum possible partial weight-bearing with two crutches.	- Weight-bearing with a single crutch or full weight-bearing. - Full extension while walking. - Good quadriceps control. - No increased effusion/edema.	- Advanced strengthening exercises. - No increase in effusion. - AROM 125 degrees. - Normal patellar mobility.	- Full ROM-kinetic quadriceps strengthening exercises. - Full AROM. - Normal patellar mobility. - No increase in effusion. - No patellofemoral pain.	- Initiation of jogging. - No effusion seen with aerobic exercise. - No pain.	- Return to sports. - Athlete feeling better and confident. - 85% success rate in test results.
Treatment	- Pain assessment. - Effusion/edema check. - Mobilization of the patella. - Passive extension. - Electric stimulation of the quadriceps/ biofeedback. - AROM exercises.	- Effusion/edema check. - Mobilization of the patella. - AROM/PROM. - Electric stimulation of the quadriceps/ biofeedback. - Closed chain kinetic exercises. - Scar massage.	- Stretching exercises. - Mobilization of the patella. - AROM/PROM exercises. - Proprioceptive exercises. - Endurance exercises. - Increasing endurance with closed kinetic exercises.	- Isotonic exercises. - Aerobic program. - Isokinetic exercises.	- Isokinetic exercises. - Aerobic exercises. - Adapted proprioceptive sports exercises. - Isokinetic exercises.	- Isotonic exercises. - Aerobic exercises. - Adapted proprioceptive sports exercises. -Isokinetic exercises.