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Evaluation of proprioceptive balance results of amateur athletes following anterior cruciate ligament reconstruction: Hamstring autograft

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ABSTRACT

Aim: Anterior cruciate ligament (ACL) is one of the main ligaments which provide mechanical stability of the knee, control the anteroposterior translation and rotation movements and play a key role in neuromuscular stability. The aim of the present study is to compare the 6th month balance results on operated and non-operated sides of athletes who underwent ST/G anterior cruciate ligament reconstruction (ACL).

Material and Method: The study was evaluated as a retrospective cohort consisting of patients who underwent semitendinosus/gracilis hamstring autograft (ST/G) ACL reconstruction (n=24) technique between May 2020 and October 2021. CSMI-TecnoBody PK-252 was used to determine the 6th month post-operative static balance measurements of patients. The tests were applied to both ACLR side and contralateral healthy side.

Results: Compared to pre-operative levels, there was a significant improvement in the mean Lysholm, Tegner, and IKDC scores at the post-operative level ($p<0.05$). No significance was found between 6th month post-operative static balance results of the subjects on ACLR side and contralateral healthy side ($p>0.05$).

Conclusion: It is seen that 6 month post-operative findings of ST/G ACLR technique show similar results with the healthy contralateral side. This result is valuable in terms of balance scores showing similar results for both sides.

Keywords: Proprioception, balance, postural control, ACL reconstruction, athletes

INTRODUCTION

Anterior cruciate ligament (ACL) is one of the main ligaments which provide mechanical stability of the knee, control the anteroposterior translation and rotation movements and play a key role in neuromuscular stability because it is involved in the sensory feedback of joint movement (1-4). ACL rupture, which is one of the most common injuries in athletic population, is among the most common orthopedic surgical procedures performed in sports medicine (5). Especially in athletes, ACL injuries typically occur due to sudden deceleration, changes in direction or strong reactions to the knee (6).

Lack of neuromuscular control of the lower extremity is one of the main disorders that occur after ACL injuries (7). Especially after complete rupture of ACL; as a result of this damage, the responses to the stimuli decrease, sensitivity is affected, the ability to perceive movement is impaired, muscular atrophy occurs and the motor neurons in the muscles connected to the knee joint are inhibited (8-11). When the losses in this neuromuscular control are evaluated functionally, they can lead to loss of knee strength, balance and proprioception, and may also feel insecure (12-14). The proprioception and balance of patients after ACLR can be evaluated by many different methods. However, today, the devices that best evaluate the balance are the devices that are in the platform structure and provide us with all the detailed data for both static and dynamic balance.

After these losses in neuromuscular functions, ACL reconstruction (ACLR) is one of the surgical methods recommended by sports physicians and orthopaedists.

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Researchers have reported that appropriate rehabilitation programs after ACLR are among key factors for fixing neuromuscular losses of the lower extremity, providing dynamic and static joint stabilization and restoring functional movements to normal (11,15). Researchers have also reported that improvements in neuromuscular control also reduce re-injury rates (12). Although the exact time for full recovery and return to sports (RTS) after ACLR has not been reported, experts state that at least six months of rehabilitation and follow up are required (16,17).

Although different ACLR methods such as quadriceps tendon (QT), patellar tendon (PT) are used for both athletes and normal individuals after ACL rupture, one of the most frequently used methods is the method performed with hamstring autograft semitendinosus/gracilis (ST/G) tendons (18). The aim of the present study is to compare the 6th month balance results on operated and non-operated sides of athletes who underwent ST/G ACRL. In line with this purpose, the main hypothesis of our study is that 6th month balance results after ACLR will reveal similar findings in operated and non-operated sides in athletes. In our study, static balance findings were evaluated in terms of many parameters, not a single parameter. From this point of view, our research is one of the studies that examines the static balance parameters after ACL in detail.

MATERIAL AND METHOD

The study was carried out with the permission of Samsun University Clinical Researches Ethics Committee (Date: 31.08.2022, Decision No: SÜKAEK-2022/6/1). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Participants

The study was evaluated as a retrospective cohort consisting of patients who underwent semitendinosus/gracilis hamstring autograft (ST/G) ACL reconstruction (n=24) technique between May 2020 and October 2021. A priori test with GPower (Dusseldorf, Germany) 3.1 program was used for determining the number of participants (**Table 1**).

Table 1. Descriptive parameters

	Mean	S. D.	Min	Max
Age (year)	25.04	7.70	17	42
Height (cm)	180.13	6.87	170	195
Weight (kg)	80.58	11.18	63	105
BMI (kg/m2)	24.86	3.45	20.11	33.90
Follow up(month)	7.46	1.14	6	9
Operated knee	R 13 (54 %)	L 11 (46 %)		

S.D standard deviation; Min minimum; Max maximum; BMI body mass index; R right; L left;

Inclusion criteria of the patients were as follows: male patients between 18 and 35 years of age, patients who did not have comorbid meniscal, chondral or other ligamentous injuries, patients who had isolated ACL rupture only on one knee, patients who did not have a history of another neuromuscular or musculoskeletal system injury and contralateral knee surgery or injury. All of the patients were actively engaged in amateur sports. Lysholm, Tegner and International Knee Documentation Committee (IKDC) scores of the patients were evaluated pre-operatively and at 6th month post-operatively. All participants were referred to the same rehabilitation specialist after surgery in order to reduce variability in the recovery period.

Semitendinosus/Gracilis Autograft Method

Semitendinosus and gracilis tendon autografts taken from the same leg are used in ST/G ACLR. Gracilis and semitendinosus tendon grafts were harvested. Both tendons fold in two to form a four-strand graft. For the preparation of the femoral tunnel, the knee was moved to 90 degrees of flexion, and the guidewire inserted from the anteromedial portal was placed over the top, 2mm in front of the posterior cortex, and the femoral tunnel was opened. To create the tibial tunnel, a tibial guide was inserted into the anterior horn of the meniscus, 6 mm anterior to the posterior cruciate ligament. Suspension fixation is used to fix the graft to the femur, while interference screw fixation is used to fix it to the tibia. Fixation was done in the same way in all patients.

Procedures

Lysholm, Tegner, IKDC scores (pre and post-operative 6th month) measurements of all patients were taken. The patients visited the laboratory two times in total, including pilot measurements. At the first visit, the patients were asked to fill in the subjective surveys consisting of Lysholm, Tegner and IKDC scales and they were familiarized with the static balance measurements planned for the next visit. At the second visit (post-operative 6th month), the patients filled in Lysholm, Tegner and IKDC scales for the second time, their anthropometric measurements were taken and static balance measurements were applied.

Determination of Static Balance

CSMI-TecnoBody PK-252 was used to determine the static balance measurements of the patients. The patients were placed on the platform of the device and all tests were performed as eyes open and eyes closed for both feet, and as only eyes open for single foot. During the measurements, measurements for both feet were taken with the patient's feet on the platform of balance device, at shoulder width, with the feet on

the lines representing the x and y axes of the platform and at equal distance from the starting point, while measurements for single foot were taken with the foot placed on the middle point where the x and y axes on the platform intersected. In both double and single foot measurements, each test took 30 seconds and during the test, body position and position of the subject were monitored from the screen. At the end of the test, the results were automatically recorded in the device and then prepared for analysis. 1 minute rest period was given between the tests. Before all tests, a trial test was performed for each measurement so that the students could familiarize with the platform.

Data Analysis

SPSS 21. package program was used in the statistical analysis of the study. The results were presented as mean and standard deviation. Shapiro–Wilk test was used for normality assumption, while Levene's test was used for homogeneity assumption. Paired sample test was used to compare paired groups (operated-non-operated and pre-post). In addition, in the comparison of paired groups, effect sizes were found according to Cohen's d effect size (M2 – M1)/SDpooled). According to this formula, a d value of <0.2 was defined as weak effect size, while a d value of 0.5 was defined as moderate and a d value of >0.8 was defined as strong effect size. The statistical results were assessed within significance level of p<0.05.

RESULTS

Compared to pre-operative levels, there was a significant improvement in the mean Lysholm, Tegner, and IKDC scores at the post-operative level (p<0.05) (**Table 2, Table 3**).

Post-operative 6th month static balance values of the patients were compared in **Table 4**. According to the results, no statistical significance was found in COPX (p=.928, 95% CI= -1.81- 1.98), COPY (p=.053, 95% CI= -4.62- .04), FBSD (p=.643, 95% CI= -1.12- .71), MLSD (p= 1.00, 95% CI= -.43- .43), AFBS (p=.166, 95% CI= -5.40- .98), AMLS (p= 1.00, 95% CI= -2.09- 2.09), EA (p= .164, 95% CI= -162.29- 29.04), PE (p= .833, 95% CI= -.117.82- 95.82) and SI (p= .928, 95% CI= -2.05- 2.23) values (**Table 4)**.

Table 2. Comparison of pre-operative and post-operative levels of Lysholm, Tegner, and IKDC scores

	Pre-op	Post-op	p
	Mean±SD	Mean±SD	
Lysholm	70.83±15.81	97.16±2.48	p<0.001*
IKDC	51.42±7.65	91.96±4.95	p<0.001*
Tegner	6.43±1.35	6.00±1.58	p<0.001*

Compared to pre-operative levels, there was a significant improvement in the mean Lysholm, Tegner, and IKDC scores at the post-operative level (p < 0.05).

Table 3. Double feet static balance results of the patients

	Mean	S. D.	Min	Max
OPEN EYES				
COPX	3.63	3.24	.0	12.0
COPY	7.80	9.11	1.0	37.0
FBSD	6.50	1.72	3.0	11.0
MLSD	4.08	1.02	2.0	6.0
AFBS(mm/sec)	14.75	4.76	8.0	26.0
AMLS(mm/sec)	12.41	4.57	7.0	26.0
EA(mm2)	486.08	200.29	220.0	1096.0
P(mm)	639.67	187.70	352.0	1147.0
CLOSED EYES				
COPX	1.50	2.32	.0	10.0
COPY	6.54	10.94	.0	48.0
FBSD	5.88	3.37	2.0	15.0
MLSD	3.49	1.53	1.0	7.0
AFBS(mm/sec)	10.04	3.43	5.0	22.0
AMLS(mm/sec)	9.71	3.62	5.0	18.0
EA(mm2)	357.71	235.64	53.0	1036.0
P(mm)	474.08	149.71	261.0	873.0

S.D standard deviation; Min, minimum; Max. Maximum; COPX center of pressure X; COPY center of pressure Y; FBSD forward/ backward standard deviation; MLSD medium/lateral standard deviation; AFBS average forward/ backward speed; AMLS average medium/lateral speed; EA ellipse area; P perimeter.

Tablo 4. Operated and non-operated side comparisons of patients' eyes open static balance data

Variables	OP	NONOP	t	p	ES	95% CI	
	Mean±S.D	Mean±S.D				LB	UB
COPX	4.17±4.75	4.08±4.76	.09	.928	0.02	-1.81	1.98
COPY	3.96±4.48	6.25±5.01	-2.03	.053	0.48	-4.62	.04
FBSD	6.96±3.03	7.17±2.49	-.47	.643	0.08	-1.12	.71
MLSD	4.17±.80	4.17±1.07	.00	1.00	0.	-.43	.43
AFBS(mm/sec)	25.20±6.20	27.42±9.58	-1.43	.166	0.28	-5.40	.98
AMLS(mm/sec)	23.08±6.36	23.08±4.89	.00	1.00	0.	-2.09	2.09
EA(mm2)	509.00±253.89	575.63±264.81	-1.44	.164	0.26	-162.29	29.04
PE(mm)	1131.50±229.78	1142.50±334.54	-.21	.833	0.04	-.117.82	95.82
SI	1.21±2.14	1.13±2.13	.09	.928	0.04	-2.05	2.23

S.D, standard deviation; CI, confidence interval; LB, lower bound; UB, upper bound; OP opere; NONOP nonopere; COPX center of pressure X; COPY center of pressure Y; FBSD forward/ backward standard deviation; MLSD medium/lateral standard deviation; AFBS average forward/ backward speed; AMLS average medium/lateral speed; EA ellipse area; PE perimeter; SI stability index.

DISCUSSION

Retrospective cohort findings of our current study showed that static balance scores between ST/G ACLR performed sides and contralateral sides revealed similar findings. A finding close to statistical significance was found only in COPY parameter. Therefore, the main hypothesis of our study that 6th month balance results after ACLR technique would reveal similar findings in operated and non-operated sides in athletes was confirmed.

There are a large number of studies in literature examining balance and proprioception of subjects after different ACL autograft methods. A prospective cohort study showed that postural control and the risk of falling reached the highest scores in 4th week after ACLR, while positive recovery scores were shown after 12th week until 6th month. However, it was stated in the same study that pre-operation waiting times after ACL rupture were directly related to postural control and the risk of falling (19). Another study compared the 6th month post-operative balance scores of patients who received patellar tendon and hamstring autograft and healthy individuals and as a result found that patients who underwent ACLR showed similar balance scores with healthy individuals (20).

In a study in which balance and proprioception of patients with medial meniscal suture following ACLR and those of healthy individuals were examined, similar results were found in both groups (21). Similar to the results of the present study, it was reported in a retrospective study that patients who underwent ACLR showed reduced balanced scores in anterior-posterior movements when compared with healthy individuals (22). In the same study, similar to the results of the present study, researchers found that the balance results on ACLR side and contralateral healthy side were similar. When centre of pressure (COP) values were compared with healthy controls in other studies conducted, it was found that ACLR groups showed impaired postural control (11,23,24). This shows that, as reported in Howells et al. (22), results of both ACRL and contralateral non-operated sides which were found to be different than the control group but similar to each other show that ACRL causes bilateral balance disorders, but not unilateral balance disorders. Researchers suggest that disorders that manifest bilaterally change sensorimotor feedback from ACRL limb, affecting postural control when standing on the contralateral limb (25-27). Another group of researchers suggested that when ACL mechanoreceptors are simulated on the one side, reflex motor activities are similarly induced on both limbs (28). Such assumptions can be confirmed with the results of our study and it can be argued that feedback from ACL is important for bilateral postural control. A radiological study which was conducted on patients with completely ruptured ACL and those who did not undergo any ACLR was compared with a control group, and bilateral balance asymmetries in ACLR group was attributed to neuroplastic changes in MR results (29). Although the researches show that ACLR sides and healthy sides have similar balance scores, future studies should examine the healthy sides with different methods to determine whether they have a symptom that will affect the answers in the balance scores, and the results that can be determined exactly the similarities between the ACLR parties should be sought.

While the reasons why patients show similar balance results on both sides after ACLR have been associated with neural transmissions, researchers have reported that another reason for this change in balance elements may be caused by damage to hamstring and quadriceps muscles during ACLR (22). Hamstring muscles are known to be an important muscle group in terms of posture control and balance. Damage that occurs in hamstring mechanoreceptors after ACLR may cause mechanical traumas and incomplete functioning of the hamstring muscle group in reflexive activities by using tendons such as semitendinosus and gracilis, which are hamstring tendons, in graft selection. Researchers have shown that the hamstring muscle group responds significantly to stimuli to ACL (30,31). The use of ST/G ACLR hamstring autograft method to the subjects in our current study reveals the idea that our balance results occur due to damage in hamstring muscle. This was also reflected in our both anterior-posterior and medial-lateral results. The fact that our balance results were similar to ACLR in contralateral sides is thought to be due to the theory presented above that unilateral ACLR causes bilateral balance disorders.

When the findings of our study are evaluated in terms of RTS, it is seen that the athletes have positive findings in terms of returning to physical activity in the 6th month. Although the isokinetic strength tests or single leg hop test procedures required for RTS were not applied in our study, the researchers who applied these test procedures at the 6th month after ST/G ACLR stated that it was appropriate to return to sports (13,32,33). When evaluated with all factors, it is seen that the 6th month after ST/G ACLR is a suitable process for athletes to start sports in terms of both lower extremity strength and balance.

When all these results are evaluated, one of the main limitations of our study is revealed. In our study, healthy controls with similar fitness levels confirmed by MRI were not evaluated, only ACLR sides and contralateral healthy sides were evaluated. This has caused us not to be able to explain the similarities between contralateral sides and ACLR sides clearly. Including both patients who use different autograft methods and healthy controls in future studies will enable evaluating results more clearly.

CONCLUSION

As a result of our study, it can be seen that ST/G ACLR technique post-operative 6th month findings show similar results with healthy contralateral side. However, testing a similar experimental design with different autograft methods and healthy controls will show clearer results in terms of evaluating the effects of ST/G ACLR method on postural control and balance.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Samsun University Clinical Researches Ethics Committee (Date: 31.08.2022, Decision No: SÜKAEK-2022/6/1).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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