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Comparison of Muscle Strength and Functional Status of Patients with Operated and Non-Operated Chronic Total Anterior Cruciate Ligament Injury

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Abstract

Background. The anterior cruciate ligament (ACL) plays a fundamental role in maintaining knee joint stability, primarily by preventing the forward translation of the tibia relative to the femur. The functional effects of ACL injuries can be seen in patients, irrespective of their surgical intervention.

The aim of the study — to compare knee functional results, quality of life, quadriceps and hamstring muscle strengths, and muscle thickness differences using ultrasonography between patients diagnosed with total anterior cruciate ligament injury who have undergone surgery and those who have not.

Methods. Male patients aged 18 to 40 with total ACL rupture were evaluated during chronic period. The study evaluated patients' pain levels, joint range of motion, thigh circumference measurements using the visual analog scale, and quadriceps and hamstring muscle thickness measurements using ultrasonography. Functionality was assessed using the single-leg jump test, Lysholm Knee Scale, and Anterior Cruciate Ligament Quality of Life Questionnaire.

Results. The study involved 21 non-operated and 20 operated patients. The rate of rehabilitation was significantly higher in the operated group, despite no significant difference between the groups in terms of the injured side. Furthermore, the operated group exhibited a statistically significant difference in thigh circumference between the right and left sides. The evaluation conducted by USG found a significant difference in hamstring muscle thickness between the operated group and the control group. However, there was no significant difference observed between the groups in terms of knee functionality, as indicated by the Lysholm knee scale and jump tests, and flexor and extensor isokinetic muscle strengths.

Conclusion. Patients with anterior cruciate ligament injuries may exhibit no significant difference between knee functionality and isokinetic muscle strength evaluations, regardless of whether they have undergone surgery or not. However, the group that underwent surgery showed significant muscle loss.

Keywords: anterior cruciate ligament injury; functionality; isokinetic muscle strength; surgery.

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Сравнение мышечной силы и функционального состояния оперированных и неоперированных пациентов с полным разрывом передней крестообразной связки

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Реферат

Актуальность. Передняя крестообразная связка (ПКС) играет ключевую роль в поддержании стабильности коленного сустава, предотвращая смещение большеберцовой кости вперед относительно бедренной кости. Функциональные последствия повреждений ПКС наблюдаются у пациентов независимо от тактики их лечения.

Цель исследования — сравнить функциональное состояние колена, качество жизни, силу четырехглавой мышцы и подколенного сухожилия, а также толщину мышц с помощью ультразвукового исследования у пациентов с тотальным разрывом передней крестообразной связки, перенесших операцию, и тех, кого лечили неоперативно.

Материал и методы. Были обследованы пациенты мужского пола в возрасте от 18 до 40 лет с полным разрывом ПКС в хронической стадии. В ходе исследования оценивались уровень боли, амплитуда движений в суставе, измерения окружности бедра при помощи визуальной аналоговой шкалы, а также измерения толщины четырехглавой мышцы и подколенного сухожилия с помощью ультразвукового исследования. Функциональное состояние оценивалось путем проведения теста с прыжками на одной ноге, по шкале Lysholm и опроснику ACL-QoL (Anterior Cruciate Ligament Quality of Life).

Результаты. В исследовании приняли участие 21 пациент, пролеченный без оперативного вмешательства, и 20 пациентов, перенесших операцию. Скорость реабилитации была значительно выше в группе прооперированных пациентов, несмотря на отсутствие существенных различий между группами с точки зрения состояния поврежденной стороны. Кроме того, в группе прооперированных пациентов наблюдалась статистически значимая разница в окружности бедра между правой и левой сторонами. Результаты УЗИ позволили выявить значительную разницу в толщине мышц подколенного сухожилия между группами. Однако между группами не наблюдалось существенной разницы в функциональности колена, о чем свидетельствовали результаты шкалы Lysholm и прыжковых тестов, а также в изокинетических показателях силы мышц-сгибателей и разгибателей.

Заключение. У пациентов с повреждениями передней крестообразной связки может не наблюдаться существенной разницы между функциональным состоянием колена и изокинетическими показателями силы мышц независимо от того, подвергались они хирургическому вмешательству или нет. Однако в группе пациентов, перенесших операцию, наблюдалась значительная потеря мышечной массы.

Ключевые слова: повреждение передней крестообразной связки; функциональность; изокинетическая мышечная сила; операция.

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INTRODUCTION

The anterior cruciate ligament (ACL) plays a fundamental role in maintaining knee joint stability, primarily by preventing the forward translation of the tibia relative to the femur [1]. The function of the stabilizer is to act as a key mechanical stabilizer, especially during dynamic movements involving pivoting, sudden stops, or directional changes. In the field of knee ligament research, the ACL has been identified as the most frequently injured structure. This observation has led to the conclusion that ACL injuries represent the most prevalent type of ligament injury within the knee joint [1, 2]. In the United States alone, the incidence of ACL injuries exceeds 200.000 cases per annum, thus emphasizing the widespread nature of this clinical problem and its significant burden on healthcare systems [3]. The injuries sustained in such incidents predominantly affect a younger, more physically active population, including athletes and individuals participating in high-demand physical activities. It is estimated that approximately 65% of ACL injuries occur during sporting activities. Notably, 70% of these injuries are attributed to non-contact mechanisms, such as sudden deceleration, cutting, or landing awkwardly after a jump, rather than direct trauma [4, 5].

The objective of treating ACL injuries is to alleviate pain and instability in the knee and restore the knee function [6]. However, the optimal treatment for ACL injuries is not yet definitive. Although surgical treatment is commonly performed, it may increase the risk of complications. Furthermore, surgical intervention improves static knee stability. A number of studies have indicated that there is no substantial discrepancy in knee functionality, sports performance, or objective measurements of muscle strength in the surrounding musculature when comparing patients who have undergone ACL reconstruction with those managed non-operatively [7, 8, 9, 10].

The aim of the study — to compare knee functional results, quality of life, quadriceps and hamstring muscle strengths, and muscle thickness differences using ultrasonography between patients who have undergone surgery and those who have not.

METHODS

This cross-sectional, single-blinded, analytical study involved male patients aged 18-40 who had experienced a total ACL rupture on knee MRI within the past 6 months. Only patients with unilateral ACL rupture who had undergone surgery with hamstring autograft and anatomical-single band technique or had at least 6 months since the ACL injury were included. Furthermore, patients with a Tegner Activity Scale (TAS) score of ≥ 4 were considered for the study. The study excluded patients with specific conditions, such as posterior cruciate ligament rupture accompanying total ACL rupture, articular cartilage damage, chondromalacia patella, stage III collateral ligament damage, accompanying fracture, traumatic injury or surgery on the other knee, partial anterior cruciate rupture, a history of recurrent ACL surgery, and intra-articular effusion.

The study participants provided detailed information on their age, occupation, education level, weight, height, body mass index, presence of trauma, injured knee side, dominant knee, date of injury, date of operation, presence of rehabilitation, and slipping sensation. Pain levels were evaluated using the Visual Analog Scale (VAS). Additionally, the front part of each participant's knee was covered with tape prior to evaluation.

The investigators performed the physical examination, ultrasonography (USG), and isokinetic evaluation while blinded. Joint range of motion (ROM) measurements were taken using a goniometer on a hard surface, and the degrees of flexion and extension were recorded. TAS was used to determine the pre-injury activity levels of the patients. Additionally, the anterior drawer test was utilized to compare the operated and non-operated groups. The anterior drawer test was considered positive if anterior tibial translation greater than 6 mm was observed compared to the contralateral side, along with a soft end-point, in accordance with standard clinical definitions. Thigh circumference measurements were confidently taken bilaterally in centimeters using a tape measure, at the same distance from the medial malleolus of the tibia.

The study measured the hamstring and quadriceps muscle thicknesses twice in both legs of the patients using USG, following the methodology described in the literature. The quadriceps muscle thickness, which includes the *vastus intermedius* and *rectus femoris*, was measured with the knee in full extension while the patient was in a supine position. The midpoint of the patella was marked using 50% of the distance between the spina iliaca anterior superior (SIAS) and the midpoint of the patella (Figure 1).

The *vastus intermedius* and *rectus femoris* muscles were each measured twice at the same point for both legs, and the average of the two measurements was taken for each leg. The patient was positioned prone and the knees were extended to measure hamstring muscle thickness. The study measured the hamstring surface cross-sectional area and the difference in muscle thickness between both legs. Measurements were taken twice from the same point for each leg and the average was calculated separately for each leg. The maximum cross-sectional area of the hamstring was found at the greater trochanter and 60% of the lateral knee (Figure 2).

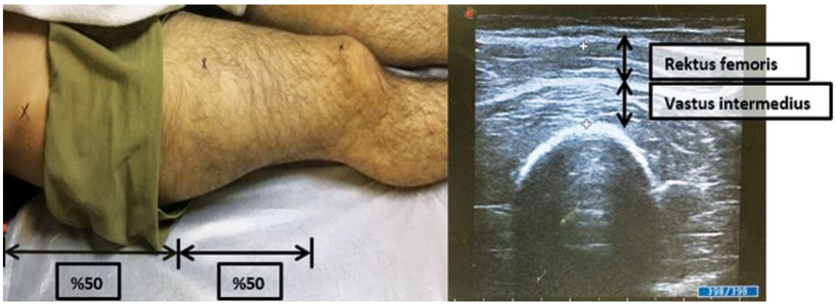

Figure 1. Ultrasonographic measurement location of *m. rectus femoris* and *m. vastus intermedius*

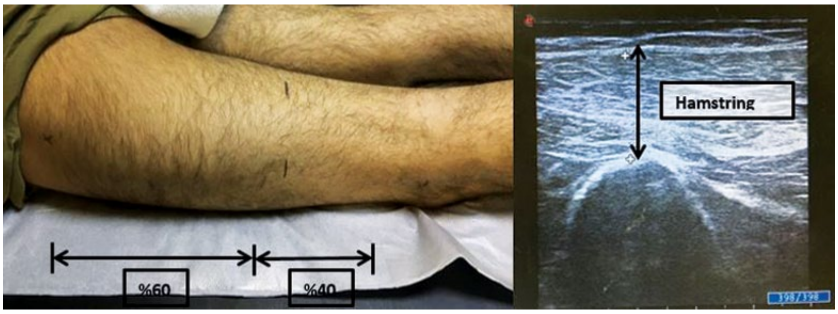

Figure 2. Ultrasonographic measurement location of the hamstring muscles

To evaluate the patients' functional status, we conducted single-leg jump tests twice on each extremity and completed the Lysholm Knee Scale (LKS) [11]. Our study measured the distance and time of a single-leg 6-meter jump. The farthest distance jumped with one leg while wearing sports shoes on hard ground determined the single-leg jump distance. Using the Limb Symmetry Index (LSI), the jump test evaluated both extremities for symmetry, with results of 90% and above considered symmetrical and results below 90% considered asymmetrical [12]. The single-leg 6-meter jump test required patients to jump 6 meters on one leg, and the time was measured with a stopwatch. The test was performed twice for both extremities, and the average time in seconds was recorded.

The Anterior Cruciate Ligament-Quality of Life questionnaire (ACL-QoL) [13] assessed the quality of life for both groups of patients. A higher score indicates a better quality of life. The questionnaire was completed by all patients, and the average score for each of the five subheadings was calculated by averaging the scores of the items.

The study conducted an isokinetic knee flexion and extension muscle strength test using a Cybex-350® dynamometer, with the assessor blinded. The patients were positioned on the device with their trunks at an angle of 80-85° with the hips and fastened to the chair with tapes over the trunk, pelvis, and thighs. Additionally, patients held onto the handles on both sides of the dynamometer seat during the test. Before the test, each patient completed a 10-minute warm-up program on a bicycle ergometer. Following this, the patients underwent a 3-minute stretching routine for their quadriceps and hamstring muscles before being tested. The test protocol consisted of 4 trials with 4 repetitions at a speed of 60°/s, and 5 trials with 20 test repetitions at a speed of 240°/sec. Throughout the test, verbal motivation was provided to the patients. At the end of the test, peak torque values, percentages of peak torque (PT) values according to body weight (BW) (PT/% BW) and total work (TW) done were recorded for both knees.

Statistical analysis

The research data was analyzed using SPSS (Statistical Package for Social Sciences) for Windows 22.0 (SPSS Inc, Chicago, IL). Descriptive statistics are presented as mean±standard deviation, median [Q_1; Q_3] (min-max), frequency distribution, and percentage. Categorical variables were evaluated using Pearson's chi-square test, Yates's corrected chi-square test, and Fisher's exact test. The normal distribution suitability of the variables was examined using the Shapiro-Wilk test. Statistical significance between two independent groups for variables that complied with normal distribution was determined using the Student's t-test. For variables that did not comply with normal distribution, the Mann-Whitney U test was used. The relationship between variables was evaluated using Spearman´s correlation analysis. We accepted a statistical significance level of $p < 0.05$.

RESULTS

The study analyzed 41 patients with ACL rupture, with 51.2% (21 patients) treated operatively and 48.8% (20 patients) — non-operatively. The demographic data of the patients is presented in Table 1. No statistically significant differences were found between the age, height, weight, BMI, education level, time since injury, injured tissues, affected and dominant knee, pre-injury TAS, duration, and type of rehabilitation for those receiving it ($p > 0.05$).

However, those who underwent surgery had a significantly higher rate of rehabilitation compared to those who did not undergo surgery ($p < 0.05$). The patients' operation-related characteristics were examined, revealing a median time of 30 months (7-42 months) since the operation and a median time of 5 months (1-26 months) from injury to operation. The majority of patients (71.4%) underwent a "hamstring autograft + meniscus repair", while the remaining 28.6% underwent only a "hamstring autograft".

The examination results demonstrate a statistically significant increase in anterior drawer test positivity in non-operated patients ($p < 0.05$). Moreover, non-operated patients exhibited a significantly lower diameter difference between the affected and intact thighs compared to operated patients ($p < 0.05$). Lastly, operated patients demonstrated a significantly higher difference in hamstring muscle thickness between the affected and healthy side ($p < 0.05$). There was no significant difference in quadriceps muscle thickness between the affected and unaffected areas, as well as affected hamstring muscle thickness ($p > 0.05$). However, the operated group demonstrated a significantly higher difference in intact hamstring muscle thickness and healthy/affected side hamstring muscle thickness compared to the non-operated group ($p < 0.05$). No statistically significant differences were found between the study groups in terms of slipping sensation, right and left thigh diameter, LKS score, knee function degree according to LKS, and asymmetry according to the distanced single-step jump test ($p > 0.05$). Furthermore, all patients exhibited symmetrical single-leg 6-meter jumps during the test time.

The LKS score was significantly higher in the rehabilitation group ($p < 0.05$) when compared to non-operated patients who did not receive rehabilitation. Additionally, the rates of being symmetrical in the single-leg hop test and having good to excellent knee function were significantly higher among non-operated patients who received rehabilitation ($p < 0.05$). No statistically significant difference was detected between the non-operated patients who received rehabilitation and those who did not in terms of the anterior drawer test, slipping sensation, affected and intact thigh diameter and differences, affected and intact quadriceps femoris and hamstring muscle thickness ($p > 0.05$) (Table 2).

Table 1

Demographic characteristics of patients

Parameter	Operated (n = 21)	Non-operated (n = 20)	p
Age (y.o.), M±SD	29.43±5.01	28.45±7.02	0.611[a]
Body weight (kg), M±SD	81.91±15.16	74.08±9.71	0.057[a]
Height (cm), M±SD	175.81±7.43	173.90±6.84	0.398[a]
BMI (kg/m^2), M±SD	26.36±3.82	24.50±2.93	0.089[a]
Education, n (%)			
High school	12 (57.1)	11 (55.0)	0.890[b]
University	9 (42.9)	9 (45.0)	
Time since injury (month), Me [Q_1; Q_3]	35 [24; 38]	20.5 [13.8; 34.3]	0.053[c]
Injured tissue, n (%)			
Anterior cruciate ligament	6 (28.6)	4 (20.0)	0.719[d]
Anterior cruciate ligament + meniscus	15 (71.4)	16 (80.0)	
Injured knee side, n (%)			
right	8 (38.1)	14 (70.0)	0.083[b]
left	13 (61.9)	6 (30.0)	
Dominant knee, n (%)			
right	18 (85.7)	20 (100)	0.232[d]
left	3 (14.3)	0	
Rehabilitation status, n (%)			
Non-taken	3 (14.3)	10 (50.0)	**0.034[b]**
Taken	18 (85.7)	10 (50.0)	
Rehabilitation duration (month), Me [Q_1; Q_3]	2 [0.7; 7.0]	0.5 [0.0; 3.5]	0.944[c]
Rehabilitation program, n (%)			
Home exercise program	9 (50.0)	7 (70.0)	0.434[d]
Supervised by a physiotherapist	9 (50.0)	3 (30.0)	
Tegner activity scale, Me (min-max)	7 (5-9)	7 (3-9)	0.739[c]

M — mean; SD — standard deviation; BMI — body mass index; [a] — Student's t-test; [b] —Yates's corrected chi-square test; [c] – Mann-Whitney U test; [d] — Fisher's exact test.

Table 2

Distribution of laxity status, functional status, quality of life, and muscle diameter and thickness among study groups

Parameter	Operated (n = 21)	Non-operated (n = 20)	p
Anterior drawer test, n (%)			
(-)	18 (85.7)	9 (45.0)	**0.004**[a]
(1+)	3 (14.3)	3 (15.0)	
(2+)	0	8 (40.0)	
Anterior drawer test group, n (%)			
Negative	18 (85.7)	9 (45.0)	**0.016**[b]
Positive	3 (14.3)	11 (55.0)	
Slipping sensation, n (%)			
(-)	16 (76.2)	11 (55.0)	0.271[b]
(+)	5 (23.8)	9 (45.0)	
Injured thigh diameter, cm, M±SD	59.50±6.18	57.80±5.47	0.433
Healthy thigh diameter, cm, M±SD	60.62±6.61	58.12±5.45	0.230
Thigh diameter differences, cm, Me [Q_1; Q_3]	1 [0.0; 1.5]	0.0 [-0,5; 0.6]	**0.021**
Injured quadriceps femoris muscle thickness, mm, M±SD	27.79±6.49	25.49±6.52	0.901
Healthy quadriceps femoris muscle thickness, mm, M±SD	30.48±6.78	26.48±6.84	0.901
Quadriceps femoris muscle thickness differences, mm, Me [Q_1; Q_3]	3.4 [0.1; 5.4]	0.0 [-0.9; 3.0]	0.570
Injured hamstring muscle thickness (mm), M±SD	31.27±8.40	26.80±7.02	0.570
Healthy hamstring muscle thickness (mm), M±SD	35.04±8.23	26.89±7.52	0.324
Hamstring muscle thickness differences (mm), Me [Q_1; Q_3]	4.65 [-3.2; 5.6]	0.6 [-1.8; 2.5]	0.730
Lysholm knee scale, Me [Q_1; Q_3]	90 [73; 96]	81.5 [72.8; 94.3]	0.367[d]
Bad, n (%)	2 (9.5)	3 (15.0)	0.737
Moderate, n (%)	6 (28.6)	8 (40.0)	
Good, n (%)	5 (23.8)	4 (20.0)	
Perfect, n (%)	8 (38.1)	5 (25.0)	
Distanced one-step jump test, n (%)			
Asymmetric	3 (14.3)	5 (25.0)	0.454[b]
Symmetric	18 (85.7)	15 (75.0)	
Timed one-step jump test, n (%)			
Asymmetric	0	0	–
Symmetric	21 (100)	20 (100)	
ACL-QoL, Me [Q_1; Q_3]			
Symptoms and physical complaints	100.3 [70.5; 108.3]	89.3 [52.8; 105.5]	0.375 [d]
Work-related concerns	112.3 [84.5; 115.0]	73.4 [45.4; 101.0]	**0.011**[d]
Hobbies, sports or competition participation	64.9 [36.1; 106.0]	29.0 [16.3; 74.6]	**0.047**[d]
Life style	102.8 [62.7; 110.2]	71.9 [46.2; 103.1]	0.167[d]
Social and emotional	82.0 [45.8; 109.0]	40.0 [21.2; 82.9]	**0.020**[d]
Total	469.9 [308.6; 529.8]	318.7 [184.3; 447.7]	**0.030**[d]

M — mean; SD — Standard deviation; ACL-QoL — Anterior Cruciate Ligament-Quality of Life; [a] — chi-square test; [b] — Fisher's exact test; [c] — Student's t-test; [d] — Mann-Whitney U test.

The sub-factor scores of the ACL-QoL for "work-related concerns", "hobbies, participation in sports or competition", and "social and emotional" as well as the total score of the non-operated patients were significantly lower than those of the operated patients ($p < 0.05$). There was no significant difference between the groups in terms of the "symptoms and physical complaints" and "lifestyle" sub-factor scores of the ACL-QoL ($p > 0.05$). In non-operated patients who received rehabilitation, the ACL-QoL total score and the sub-factor scores of symptoms and physical complaints, hobbies, participation in sports or competitions, lifestyle, social, and emotional were significantly higher than in non-operated patients who did not receive rehabilitation ($p < 0.05$).

No statistically significant differences were found in isokinetic measurements for extension and flexion between the two groups ($p > 0.05$). However, a statistically significant difference was observed in PT/BW at 60°/sec angular speed, PT/BW at 240°/sec, TW, and TW/BW values at 240°/sec on the affected side during flexion when comparing non-operated patients who received rehabilitation to those who did not ($p < 0$). There was no significant difference found in all isometric measurements in extension ($p > 0.05$) and other isometric measurements in flexion. Furthermore, there was no significant difference observed between non-operated patients who received rehabilitation and those who did not, in terms of hamstring/quadriceps ratios at 60°/sec and 240°/sec on both the affected and healthy sides ($p > 0.05$).

Table 3 demonstrates the relationship between the ACL-QOL questionnaire and various factors, including age, body mass index, time since injury, TAS score, LKS score, and thigh diameter and muscle thickness differences, based on the operating status. The LKS score and the ACL-QOL questionnaire total score, as well as the scores for symptoms and physical complaints, work-related concerns, hobbies, participation in sports or competitions, life style, and social and emotional factors were all evaluated and found to have a strong correlation ($r = 0.71$, $r = 0.74$, $r = 0.67$, $r = 0.71$, $r = 0.56$, $r = 0.61$, respectively; $p < 0.05$). The study clearly demonstrates a positive and statistically significant relationship between the sub-factor scores of the operated patients. A positive and strong correlation was found in non-operated patients between LKS score and ACL-QOL questionnaire total score, as well as symptoms and physical complaints, work-related concerns, hobbies, participation in sports or competitions, life style, and social and emotional sub-factor scores ($r = 0.68$, $r = 0.63$, $r = 0.58$, $r = 0.68$, $r = 0.56$, $r = 0.61$; $p < 0.05$, respectively).

The relationship between affected side isokinetic measurements and ACL-QOL scores of operated and non-operated patients is also shown in Table 4.

Table 3

The relationship between the ACL-QoL questionnaire score and various factors, based on the operating status

Factors	ACL-QoL subscales					
	Symptoms and physical complaints	Work-related concerns	Hobbies, sports or competition participation	Life style	Social and emotional	Total
Operated (n = 21)						
Age	-0.106	-0.128	-0.131	-0.097	-0.150	-0.095
BMI	-0.083	-0.215	-0.048	0.008	-0.026	-0.086
Time since injured	-0.054	0.127	-0.175	-0.231	-0.064	-0.104
Tegner activity scale	0.354	0.354	0.363	0.297	0.246	0.371
Lysholm knee scale	**0.743****	**0.666****	**0.709****	**0.560****	**0.608****	**0.707****
Thigh diameter differences	0.370	0.357	0.347	0.255	0.379	0.374
Quadriceps muscle thickness differences	0.213	0.250	0.318	0.229	0.286	0.273
Hamstring muscle thickness differences	-0.411	-0.200	-0.395	-0.207	-0.404	-0.397
Non-operated (n = 20)						
Age	0.036	0.066	-0.106	-0.252	-0.248	-0.163
BMI	0.017	0.157	0.066	-0.035	0.000	-0.003
Time since injured	0.003	-0.012	0.041	-0.029	-0.185	-0.061
Tegner activity scale	0.090	0.054	-0.036	0.151	0.182	0.136
Lysholm knee scale	**0.632****	**0.580****	**0.680****	**0.565****	**0.611****	**0.680****
Thigh diameter differences	-0.027	-0.129	-0.038	-0.199	-0.096	-0.123
Quadriceps muscle thickness differences	0.223	-0.305	0.060	0.238	0.105	0.054
Hamstring muscle thickness differences	0.396	0.335	0.198	0.296	0.314	0.347

**$p < 0.01$.

Table 4

The relationship between the ACL-QoL questionnaire score and isometric muscle strength measurements of operated and non-operated patients

Parameter		ACL-QoL subscales					
		Symptoms and physical complaints	Work-related concerns	Hobbies, sports or competition participation	Life style	Social and emotional	Total
Operated (n = 21)							
Extension							
PT (60°/s)	Injured	**0.684****	**0.505***	**0.692****	**0.569****	**0.652****	**0.652****
	Healthy	0.033	-0.082	0.100	0.000	-0.077	0.050
PT%BW (60°/s)	Injured	**0.818****	**0.680****	**0.665****	**0.474***	**0.709****	**0.693****
	Healthy	0.205	0.091	0.123	-0.062	0.154	0.171
PT (240°/s)	Injured	0.299	0.157	0.428	0.403	0.383	0.364
	Healthy	0.025	-0.086	0.167	-0.021	-0.001	0.093
PT%BW (240°/s)	Injured	**0.577****	**0.480***	**0.515***	**0.433***	**0.547***	**0.531***
	Healthy	0.052	-0.033	0.063	-0.151	-0.050	0.048
TW (240°/s)	Injured	0.257	0.019	0.322	0.261	0.296	0.256
	Healthy	-0.151	-0.316	-0.026	-0.071	-0.113	-0.082
TW%BW (240°/s)	Injured	0.343	0.089	0.318	0.248	0.430	0.286
	Healthy	-0.047	-0.188	-0.157	-0.352	-0.144	-0.134
Flexion							
PT (60°/s)	Injured	**0.571****	0.241	**0.575****	0.424	0.354	**0.491***
	Healthy	0.197	-0.110	0.187	0.077	0.049	0.118
PT%BW (60°/s)	Injured	**0.653****	0.420	**0.455***	0.219	0.340	**0.438***
	Healthy	0.368	0.126	0.213	0.030	0.130	0.219
PT (240°/s)	Injured	0.264	0.077	0.381	0.403	0.236	0.290
	Healthy	0.101	-0.115	0.162	0.083	0.031	0.112
PT%BW (240°/s)	Injured	**0.467***	0.379	0.404	0.355	0.335	0.393
	Healthy	0.214	0.061	0.158	0.024	0.052	0.169
TW (240°/s)	Injured	0.427	0.083	0.397	0.198	0.309	0.329
	Healthy	0.056	-0.241	0.091	-0.032	-0.026	0.030
TW%BW (240°/s)	Injured	**0.597****	0.325	0.395	0.134	0.367	0.401
	Healthy	0.222	0.009	0.087	-0.055	-0.001	0.099
Hamstring/quadriceps (60°/s)	Injured	-0.069	-0.210	-0.194	-0.307	-0.368	-0.262
	Healthy	0.371	0.092	0.201	0.170	0.142	0.195
Hamstring/quadriceps (240°/s)	Injured	0.091	0.060	0.034	0.033	-0.140	0.000
	Healthy	0.303	0.107	0.177	0.229	0.187	0.203
Non-operated (n = 20)							
Extension							
PT (60°/s)	Injured	0.274	0.296	0.298	0.320	0.272	0.316
	Healthy	-0.136	-0.105	-0.183	-0.073	-0.048	-0.126
PT%BW (60°/s)	Injured	0.320	0.290	0.280	0.241	0.229	0.356
	Healthy	0.029	-0.035	-0.014	0.023	0.034	0.076
PT (240°/s)	Injured	**0.647****	**0.487***	0.346	0.361	0.338	**0.498***
	Healthy	0.183	-0.037	-0.047	0.063	-0.001	-0.014
PT%BW (240°/s)	Injured	**0.546***	0.358	0.320	0.341	0.303	**0.451***
	Healthy	0.169	-0.148	-0.142	-0.038	-0.147	-0.081
TW (240°/s)	Injured	**0.593****	0.343	0.332	**0.547***	0.436	**0.477***
	Healthy	0.380	0.108	0.236	0.314	0.305	0.274
TW%BW (240°/s)	Injured	**0.705****	0.388	0.398	**0.561***	0.487*	**0.584****
	Healthy	**0.571****	0.213	0.330	0.417	0.405	**0.462***

End of Table 4

Parameter		ACL-QoL subscales					
		Symptoms and physical complaints	Work-related concerns	Hobbies, sports or competition participation	Life style	Social and emotional	Total
Flexion							
PT (60°/s)	Injured	**0.501***	0.237	0.287	0.348	0.209	0.332
	Healthy	-0.058	-0.183	-0.321	-0.155	-0.248	-0.255
PT%BW (60°/s)	Injured	**0.721****	0.357	**0.487***	0.440	0.398	**0.573****
	Healthy	0.220	-0.167	-0.044	0.011	-0.004	0.020
PT (240°/s)	Injured	**0.500***	0.274	0.387	0.288	0.346	0.439
	Healthy	0.066	-0.029	-0.176	-0.020	-0.149	-0.126
PT%BW (240°/s)	Injured	**0.523***	0.227	0.380	0.316	0.348	**0.452***
	Healthy	0.317	0.113	0.023	0.138	0.005	0.121
TW (240°/s)	Injured	**0.699****	0.408	**0.492***	**0.537***	0.426	**0.565****
	Healthy	0.287	0.080	-0.085	0.093	-0.059	0.035
TW%BW (240°/s)	Injured	**0.760****	0.408	**0.507***	**0.513***	0.442	**0.611****
	Healthy	**0.528***	0.098	0.177	0.281	0.165	0.283
Hamstring/quadriceps (60°/s)	Injured	0.223	-0.142	-0.084	-0.096	-0.140	-0.065
	Healthy	-0.064	-0.104	-0.306	-0.223	-0.305	-0.271
Hamstring/quadriceps (240°/s)	Injured	0.096	-0.018	0.289	0.247	0.220	0.195
	Healthy	0.098	0.161	-0.009	0.038	-0.116	0.005

*p < 0.05; **p < 0.01.

DISCUSSION

Our study included only male patients to ensure consistency with the trend of a high prevalence of male patients in studies on ACL injuries. This is supported by T.L. Sanders et al. who reported a higher incidence of ACL injuries in men than in women in the general population (81.7 per 100.000 — men, 55.3 — women; p = 0.001) [14].

Patients with ACL lesions commonly experience pain and slipping sensation. Pain is caused by hemarthrosis in the acute period and mostly by the development of osteoarthritis in the chronic period. It is important to note that a study conducted by H. Moksnes et al. found no significant difference in VAS values between operative and non-operative ACL injuries, indicating that non-operative treatment may be a viable option for some patients [2]. In a meta-analysis by T.O. Smith et al., it was determined that the development of osteoarthritis after ACL injury occurred more after 5 years [7]. Our study evaluated patients within the first 5 years after the injury, consistent with the literature. We found no significant difference between the groups in terms of pain and slipping sensation.

The main objective of conducting a physical examination on patients with ACL injuries is to assess the stability of the knee. In this study, we utilized the anterior drawer test to evaluate knee stability and found a significantly higher rate of positive tests in the non-operated group, indicating that the knees of patients who underwent surgery were more stable. Our findings are consistent with those of H. Moksnes et al. who also found better knee stability in patients who underwent surgery [2]. Studies objectively evaluating stability using devices such as KT-1000 or KT-2000 found the operated group to be stable [2, 15]. Furthermore, there was no significant difference in functionality between the groups despite the operated group being more stable upon physical examination [8, 9, 15]. Interestingly, 45% of non-operated patients exhibited a negative anterior drawer test despite MRI-confirmed ACL ruptures. This may be due to neuromuscular adaptation over time, particularly through hamstring activation that compensates for anterior laxity. Additionally, partial scarring or fibrosis of the ruptured ACL remnant may provide some mechanical stability. Other potential factors include voluntary or involuntary muscle guarding during the test, or variability in clinical grading of borderline laxity. These findings highlight the importance of integrating clinical examination with imaging and functional assessments.

Operated and non-operated patients showed differences in muscle thickness and isokinetic measurements in thigh circumference. It is important to note that muscle thickness is correlated with muscle strength, as stated by T. Abe et al. [16]. Our study found that although the hamstring muscle thicknesses differed between the two groups, no difference was detected in the isokinetic evaluation or flexor muscle group strengths. Muscle thickness is not necessarily correlated with muscle strength. Age and gender are among the factors that may impact muscle strength.

Meniscus damage commonly accompanies ACL injuries. Meniscus damage accompanies acute ACL injuries in 16-84.7% of cases, as shown by research [17, 18, 19]. Additionally, a 6-year cohort study conducted by K.R. Duchman et al. found that this value was 65.3% [20]. Our study found that meniscus damage was present in 15 patients (71.4%) in the operated group and in 16 patients (80%) in the non-operated group.

In a prospective randomized controlled study conducted by R.B. Frobell et al., 120 active adult patients aged 18-35 were included. At the 10th week, 61 patients underwent early ACL reconstruction, while reconstruction was postponed and performed if necessary in the remaining 59 patients. Early surgical treatment resulted in significantly less instability when evaluated by Lachman and pivot-shift tests, with no significant difference in pain, symptoms, and Knee injury and Osteoarthritis Outcome Score (KOOS), SF-36 QoL questionnaire, and TAS when evaluating 5-year results. Following a five-year period of observation, it was found that knee stability at rest was statistically significantly superior in knees that had undergone early ACL reconstruction in comparison with those that had undergone initial rehabilitation, with the option of undergoing subsequent reconstruction if deemed necessary, as indicated by normal Lachman and pivot-shift tests. Additionally, there was no significant difference between the groups in terms of osteoarthritis development [10]. H. Grindem et al. conducted a study examining the 1-year results of active rehabilitation patients with ACL injuries who underwent surgery and those who did not. The non-operative group showed significantly better results in four jump tests, the Knee Outcome Survey Activities of Daily Living Scale (KOS-ADLS), and International Knee Documentation Committee (IKDC)-2000 scores, despite showing more laxity in KT-1000 measurements. Knee function and return to sports did not differ between the two groups [21].

These findings demonstrate the reliability and consistency of isokinetic tests and devices in providing objective data for the follow-up of patients with ACL injuries. The study results indicate that there was no statistically significant difference between the flexion and extension muscle peak torques, PT/BW values at an angular speed of 60°/s, and the flexion and extension peak torque, PT/BW values and total work at 240°/s in the operated and non-operated groups. Our findings are supported by the literature. H. Grindem et al. conducted a 2-year follow-up in 2014 and found no significant difference in knee flexion and extension muscle strength and knee function between operatively and non-operatively treated patients, which is consistent with our study [9]. Our study supports T.O. Smith et al. meta-analysis, which found no significant difference between flexion and extension muscle strength in the one- to four-year results [7].

Quadriceps weakness is common in ACL injuries and its etiology is multifactorial. There is less loss of strength in the hamstring muscles after ACL injury compared to the quadriceps. This supports the hypothesis that knee flexors are ACL agonists and that flexor muscle strength is less affected by compensatory mechanisms after ACL injury [22]. Neurological dysfunction was found to be less effective in the knee flexors than in the knee extensors in patients with ACL injuries, as concluded by Y. Konishi et al. [23]. Additionally, patients who underwent reconstruction with hamstring and patellar tendon autograft showed no difference in muscle strength [24].

The hamstring to quadriceps (H/Q) ratio assesses the balance between the hamstring and quadriceps muscles, and changes in this ratio may increase the risk of developing osteoarthritis after an ACL injury [25]. H.J. Kim et al. meta-analysis supports the existence of a protective mechanism in the knee after an ACL injury that reduces quadriceps isokinetic strength and theoretically increases hamstring strength to protect against tibial anterior translation. The research demonstrates that quadriceps muscle strength loss is three times greater than hamstring muscle strength loss, leading to an increased H/Q ratio in the injured leg compared to the healthy leg [26]. Our study shows that the average H/Q ratios of the injured knees in both the operated and non-operated groups at 60°/s and 240°/s were higher than those of the healthy knee.

In a review in the literature, no difference was found between surgical treatment and conservative treatment of ACL injuries in adults in terms of KOOS score, SF-36 QoL score and return to sports activity rates, but it was stated that this review was at a low level of evidence [27]. Our study found that ACL-QoL questionnaire results were significantly better in the group that underwent surgery compared to the non-operated group. The subheadings that showed significant differences were mostly related to the patients' emotional state. The patients' psychological state, fear of re-injury, and kinesiophobia may have also influenced these differences. Notably, S. Sonesson et al. conducted a study that demonstrated improved return-to-sport rates when rehabilitation included psychological factors such as motivation [28]. Psychological factors, such as kinesiophobia and fear of injury, play a significant role in determining whether an individual returns to their pre-injury level of sports activity [29].

Rehabilitation is a crucial factor that impacts the outcomes of both conservatively treated and surgically treated patients. These findings suggest that rehabilitation may not be the sole determining factor in patient outcomes and that other factors should be considered as well. Our study found that the rate of rehabilitation was significantly higher in the surgical group. However, despite the higher number of patients receiving rehabilitation in the surgical group, no significant difference was detected in functionality (LKS and jump tests) and isokinetic test results. There were no significant differences in symptoms (VAS, slipping sensation) and physical examination findings (anterior drawer test, ROM, thigh diameter differences) between the non-operated patients who received rehabilitation and those who did not. Nevertheless, patients who received rehabilitation demonstrated significantly better results in LKS and jump tests, which evaluate knee functionality. Our study found a strong and statistically significant positive correlation between all subheadings of the ACL-QoL and LKS in both the operated and non-operated groups. This confirms the findings of G.I. Kinikli et al., who reported a fair correlation (r = 0.23) between LKS and ACL-QoL in their Turkish translation of the questionnaire [13].

When we examined the literature, we could not find any studies examining the correlation between the ACL-QoL and isokinetic muscle strength. However, the relationship between isokinetic muscle strength and the SF-36 QoL questionnaire was evaluated. In this study conducted by D. Marn-Vukadinovic et al., a negative correlation was found between knee extensor weakness (60°/s PT) and physical function and social function (r = -0.59, p < 0.01 and r = -0.43, p < 0.01, respectively) [30]. Our study confirms that a reduction in knee extensor muscle strength is linked to a decline in the quality of life of knee injury patients. Furthermore, we examined the relationship between ACL-QoL subheadings and isokinetic muscle strength measurements for both the operated and non-operated groups. The study found a significant positive correlation between extension PT and PT/BW on the affected side of the operated patients at a speed of 60°/s, extension PT/BW at 240°/s, and all subheadings of the ACL-QoL. These results demonstrate the relationship between these variables. The correlation analysis of the non-operated group showed a statistically significant relationship between the “symptoms and physical complaints” subheading of the ACL-QoL and the affected side with 240°/s extension PT, PT/BW, TW, TW/BW and 60°/s flexion PT, PT/BW. Furthermore, the isometric strengths of PT, PT/BW, TW, TW/BW at a speed of 240°/s exhibited a positive difference. The operated group did not show a significant relationship between the other subheadings of the ACL-QoL questionnaire.

Study limitations

The main limitations of our study are the relatively small number of patients in the groups, the lack of pre-injury data, and the fact that it was a cross-sectional study. Prospective studies with larger patient groups are needed in the future.

CONCLUSION

There were no significant differences in knee functionality and isokinetic muscle strength between the operated and non-operated patients. However, it is worth noting that the quality of life was better in the operated group, which contradicts the literature. This could be due to the higher number of patients receiving rehabilitation in the operated group and the fact that the differing subheadings were more related to emotional and kinesiophobia.

DISCLAIMERS

Author contribution

Pınar A. Bulut — study concept, statistical data processing, data acquisition.

Aylin Ayyıldız — data acquisition, analysis and interpretation, statistical data processing, literature search and review, drafting and editing the manuscript.

Selda Ç. İnceoğlu — data acquisition, statistical data processing.

Figen Yılmaz — data analysis and interpretation, editing the manuscript.

Türker Şahinkaya — statistical data processing, data acquisition.

Osman T. Eren — data analysis and interpretation.

Banu Kuran — study concept and design, scientific guidance, editing the manuscript.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear

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ность за все аспекты работы, чтобы обеспечить надлежащее рассмотрение и решение всех возможных вопросов, связанных с корректностью и надежностью любой части работы.

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