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THE IMPACT OF ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION ON MUSCLE DIAMETER: A PRE AND POST OPERATIVE COMPARISON

DOI:
(Original scientific paper)

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Abstract

Injuries to the knee joint that result with rupture of the anterior cruciate ligament usually have a number of harmful effects on the function of the hamstring muscles. The aim of this study is to analyze the volume of the knee musculature in patients with ACL reconstruction, with two different methods in the preoperative period, 3 and 8 months after the surgical treatment in order to see the result of the same.Materials and methods: The results of an analysis of 80 subjects, in the City General Hospital"8th September" ,Skopje at the Department of Orthopedics and Traumatology are shown. The first group (40 subjects) were surgically treated with a graft in the form of a duplication from the semitendinosus and gracilis muscles, while the second group (40 subjects) were surgically treated with a graft from the semitendinosus in the form of a quadriplication. Measurements of the volume of the musculature of both groups were made pre-operatively, 3 and 8 months after the operative treatment.Results: Preoperatively, the thigh musculature of the injured limb in the SG ranged from 32 to 71 cm, with a mean of 48.22 ± 3.5 cm. In CG the circumference was in the range of 40 to 60 cm, average 50.32 ± 4.5 cm. Only 1 patient from the control group had identical musculature on both limbs.After three months of the operative intervention, patients from both groups had on average a similar circumference of the musculature of the injured limb (50.40 ± 7.7 and 51.86 ± 3.8 cm, respectively). In 3 patients from SG and 7 patients from CG, the same values were measured on both limbs. After 8 months, the circumference in the SG ranged from 34 to 74 cm, the average was 52.17 ± 7.8. In CG, the circumference was from 47 to 62 cm, the average was 53.31 ± 4.1 cm.In 17 patients from SG and in 21 patients from CG, the same values were measured on the injured and healthy limb. Conclusion: The statistical analysis after the measurements made in the period preoperatively, at 3 and 8 months after the operative treatment did not show a significant difference between the two surgical methods, but still showed us a significant increase in volume in both groups.

Key words: *graft, musculature, reconstruction, volume, ligament*

Introduction

The anatomy of the anterior cruciate ligament was described by the Egyptians 3000 years ago. Claudius Galen first described the anterior cruciate ligament (ACL) as an accessory stability structure that prevents abnormal movement of the knee. Knowledge of ACL has evolved over 1800 years, so as a result of that evolution in the beginning of the 20th century the first case of rupture was observed [1]. Surgical reconstruction of the anterior cruciate ligament (ACL) dated since the late nineteenth century when Dr. Robson performed the first successful intervention on a 41-year-old coal miner [2, 3]. Over the years, techniques have changed and improved, becoming less and less invasive. The biggest innovation happened in the eighties with the introduction of arthroscopy. Since that moment, the technique has been constantly modified and optimized in order to overcome the open surgical procedure, making the reconstruction less invasive. At the same time it reduces complications, intraoperative bleeding, postoperative pain and ensures faster recovery[4]. The All Inside technique was first described in 1995 by Morgan, while subsequently in 2006 Lubowitz published a note for the All Inside technique with breaking the femoral and tibial canal transtibially, using the RetroCutter which has the role of a retrorimer [1]. ACL has been a major focus of studies in recent decades, and its importance and fundamental role in knee stability has led to a significant amount of research studies on its anatomy [5, 6], physiology[7, 8], biomechanics [9, 10, 11], assessment

[12, 13,], rehabilitation [16, 17], as well as possible risks [14, 15]. Discontinuity of the ACL inevitably results in knee kinematics alterations, as transfer of loads can be effective only if the joint is mechanically stable. The sequelae seen after ACL injury involve quadriceps strength deficits, neuromuscular dysfunction, and biomechanical maladaptation and is associated with the development of knee osteoarthritis. The goals of ACLR in athletes are to restore normal knee joint stability and function and allow a return to sports activities [18]. Quadriceps and hamstrings weakness occurs frequently after anterior cruciate ligament (ACL) injury and reconstruction. Evidence suggests that knee injury may precipitate hip and ankle muscle weakness, but few data support this contention after ACL injury and reconstruction [19]. Muscle atrophy occurs rapidly after an ACL injury and is compounded by further atrophy during the early period of recovery after ACL reconstruction. Literature has demonstrated that leg immobilization results in rapid and significant loss of skeletal muscle mass [20]. Even after returning to play, some athletes who have undergone the surgery cannot perform as they did previously because a sense of knee instability remains and the muscle strength does not sufficiently [21]. Many surgeons advise as necessary a period of muscular strengthening before surgery in order to improve outcome after ACL. For these reasons, during the last years the concept of "prehabilitation" has emerged to optimize postoperative outcomes of ACL and to reduce the muscular deficits. With the term of prehabilitation, it is defined the period of rehabilitation before surgery, mainly focused on quadriceps strengthening and neuromuscular training [22].

Materials and methods

The study is worked at the "8 Septemvri" GOB, at the Department of Orthopedics and Traumatology in Skopje. In terms of design, the research is a prospective, clinical and interventional study. The time frame of the research covers a period of 12 months. The planned contingent of subjects consists of 80 patients who are randomly divided into two groups. The first group (40 subjects) were surgically treated with the already existing standard method used in our institution, which is the method using a graft in the form of duplication from the semitendinosus and gracilis muscles and the second group (40 subjects) were surgically treated with the new operative method, where only the semitendinosus muscle is used as a graft, in the form of a quadriplication.

Inclusion criteria

- Patients who have been diagnosed with a complete rupture of the anterior cruciate ligament.
- Patients aged 18 to 35 years.
- Patients without previous surgical interventions on the injured knee.
- Patients with previously signed informed consent for inclusion in the study.

Exclusion criteria

- Patients who have been diagnosed with a partial rupture of the anterior cruciate ligament.
- Patients diagnosed with injury to other knee ligaments.
- Patients who are younger than 18 years old, ie older than 35 years old.
- Patients with neuromuscular and other comorbidities.
- Patients with previous operative interventions on the injured knee.
- Patients with postoperative complications.
- Patients who will voluntarily leave the study.

Results

The first group (40 subject) comprised the control group (CG), surgically treated with a standard method using a graft in the form of a duplication of the semitendinosus and gracilis muscles. The second group (40 subjects) comprised the experimental group (SG), surgically treated with a method in which only the semitendinosus muscle was used as a graft in the form of a quadriplicate (Figure 1).

Preoperational, circumference of the hamstring muscles of the injured limb in the CG ranged from 32 to 71 cm, averaging 48.22 ± 3.5 cm. In the CG, the volume of the hamstring muscles of the injured limb ranged from 40 to 60 cm, averaging 50.32 ± 4.5 cm. The difference in the average volume between the two groups was statistically insignificant ($p = 0.13$) (Table 1). Comparison of the volume of the hamstring muscles of the injured and healthy limbs showed that only 1 patient from the control group had identical musculature on both limbs. In all other patients, lower values of the volume of the hamstring muscles were measured on the injured limb.

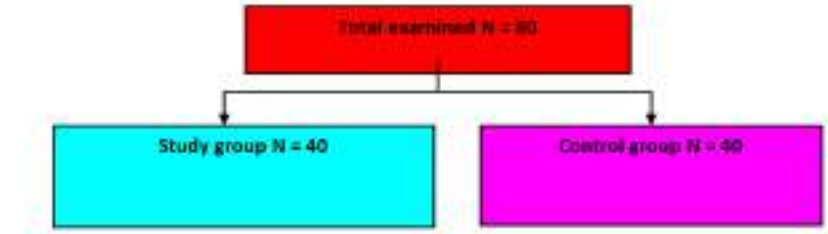

Figure 1: Description of sample

Table 1: Circumference of the hamstring muscles of the injured limb, preoperatively – SG and CG

Preoperational clinical examinations			
Group	Descriptive Statistics (circumference of the hamstring muscles of the injured limb in cm)		
	mean ± SD	min – max	p-level
SG	48,22 ± 3,5	32 – 71	t = 1,52
CG	50,32 ± 4,5	40 – 60	p = 0,13 ns

t (Student t-tests for independent samples)
SG (graft on muscles of semitendinosus)
CG (graft on muscles of the semitendinosus and gracilis)

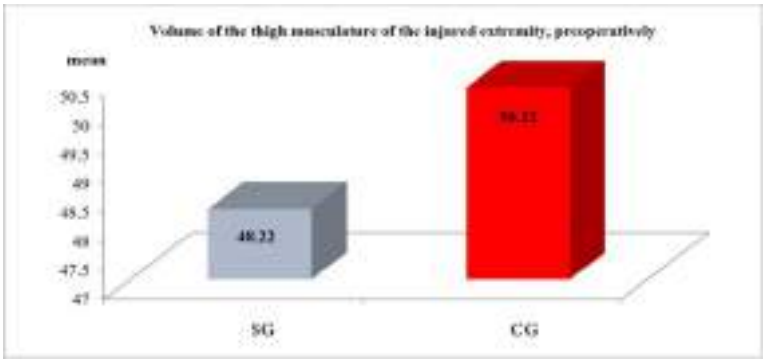

Figure 2: Graphical representation of the average circumference of the hamstring muscles of the injured limb, preoperatively –SG and CG

Table 2 shows the descriptive values (average values, minimum and maximum) of the volume of the contralateral uninjured hamstring muscles, in the parameters of both groups before the surgical intervention (Table 2)

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Table 2: Circumference of the muscle of the uninjured limb, preoperatively

Preoperational clinical examinations		
Group	Descriptive Statistics (circumference of the muscle on controlled limbs in cm)	
	mean ± SD	min – max
SG	52,92 ± 7,8	35 – 75
CG	54,06 ± 3,8	48 – 61

SG (graft on muscle semitendinosus)
CG (graft on muscle semitendinosus and gracilis)

Three months after surgical procedure, patients with semitendinosus muscle graft and patients with semitendinosus and gracilis muscle graft had similar mean circumferences of the tendon muscles of the

injured limb (50.40 ± 7.7 and 51.86 ± 3.8 cm, respectively). The difference in mean circumferences between the two groups was statistically insignificant (p = 0.28) (Table 3, Figure 3). The circumference of the tendon muscle of the injured limb in SG ranged from 33 to 73 cm, in CG it ranged from 45 to 60 cm).
Compared to the healthy limb, 3 months after surgery, 3 patients from the SG and 7 patients from the CG had the same values for the volume of the hamstring muscles in both limbs. Only 1 patient from the control group had identical muscles in both limbs as before the intervention. In all other patients, lower values of the volume of the muscles were measured on the injured limb.

Table 3: Circumference of the hamstring muscles of the injured limb 3 months after surgery – SG and CG

Group	3 months after surgical treatment		
	Descriptive Statistics (circumference of the muscle on controlled limbs in cm)		
	mean ± SD	min – max	p-level
SG	50,40 ± 7,7	33 – 73	t = 1,08
CG	51,86 ± 3,8	45 – 60	p = 0,28 ns

t(Student t-tests for independent samples)
SG (graft on muscle semitendinosus)
CG (graft on muscle on semitendinosus and gracilis)

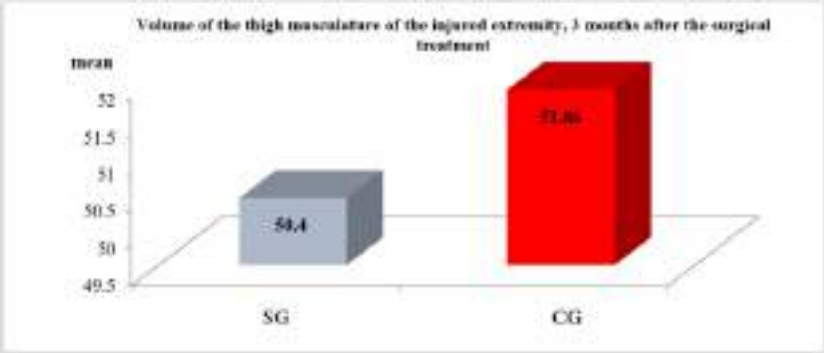

Figure 3: Graphical representation of the average circumference of the muscles on the thigh of the injured limb 3 months after surgical treatment – SG and CG

Table 4 shows the descriptive parameters (average values - minimum and maximum) of the volume of the hamstring muscles of the contralateral uninjured limb, in patients from both groups after a 3-month postoperative period.

Table 4: Circumference on muscles hamstring muscles of the uninjured limb 3 months after surgical treatment– SG and CG

Group	3 months after surgical treatment	
	Descriptive Statistics (Circumference on hamstring muscles on controlled limbs in cm)	
	mean ± SD	min – max
SG	52,92 ± 7,8	35 – 75
CG	54,06 ± 3,8	48 – 61

SG (graft muscles on semitendinosus)
CG (graft on muscles on semitendinosus and gracilis)

After 8 months of surgery, circumference of the hamstring muscles of the injured limb in the SG ranged from 34 to 74 cm, averaging 52.17 ± 7.8. In the CG ranged from 47 to 62 cm, averaging 53.31 ± 4.1 cm. Statistical analysis did not confirm a significant difference in the volume of the hamstring muscles 8 months postoperatively, depending on the type of surgical technique (p = 0.42) (table 5,figure 4).
Compared to the healthy limb after 8 months of the intervention, in 17 patients from the SG and 21 patients from the CG, the same values were measured for the volume of the hamstring muscles of the injured and healthy limb. After 3 months postoperatively, in 3 (three) patients from the CG and in 7 patients from the

CG, the same values were measured for the volume of the hamstring muscles of both limbs. Preoperatively, only 1 patient from the control group had identical muscles on both limbs. In all other patients, lower values of the volume of the hamstring muscles were measured on the injured limb.

Table 5: Circumference on muscles hamstring muscles not injured limb after 8 months postoperative treatment – SG and CG

Group	8- months after surgical treatment		
	Descriptive Statistics (Circumference on hamstring muscles on controlled limbs in cm)		p-level
	mean ± SD	min – max	
SG	52,17 ± 7,8	34 – 74	t = 0,81
CG	53,31 ± 4,1	47 – 62	p = 0,42 ns

t(Student t-tests for independent samples)
SG (graft on muscles semitendinosus)
CG (graft on muscles semitendinosus and gracilis)

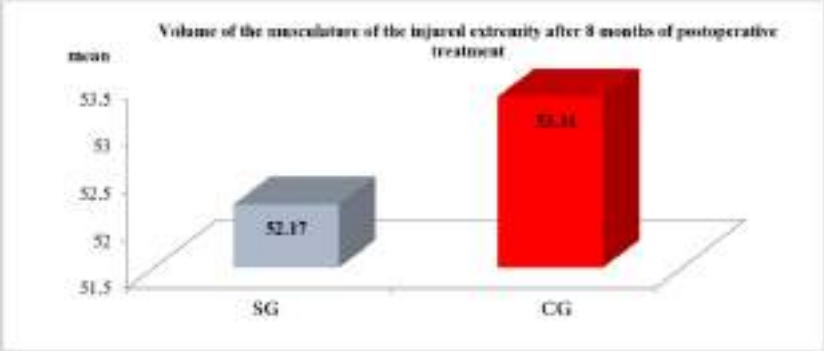

Figure 4: Graphical representations of the average circumference of the muscles of the injured limbs after 8 months postoperative treatment – SG and CG

In table 6 it is presented the descriptive parameters (average values, minimum and maximum) the circumference of the hamstring muscles of the contralateral immediate parameters, in patients from both groups, after the 8-month postoperative treatment (table 6).

Table 6: Circumference of the uninjured limb after 8 months surgical treatment – SG and CG

Group	8-months after surgical treatment	
	Descriptive Statistics (circumference of the contralateral limb musculature in cm)	
	mean ± SD	min – max
SG	53,07 ± 7,7	35 – 75
CG	54,11 ± 3,8	48 – 61

SG (графт од мускулот semitendinosus)
CG (графт од мускулите semitendinosus и gracilis)

Clinical results in SG and CG before operations, 3 and 8 months operational treatment

Circumference of the hamstring muscles of the injured limb increased significantly during the follow-up period (preoperatively, 3 and 8 months postoperatively) in both groups of patients ($p < 0.0001$) (Table 6)(Figure 5). In the SG, the average increase in the volume of the hamstring muscles at the end of the follow-up compared to the preoperative values was recorded by 8.2%, while this increase in the CG was 5.9%

Table 6: Circumference muscles on the injured limb – SG and CG

Circumference on muscles on the injured limb	SG	CG
	mean ± SD	mean ± SD
Preoperational	48,22 ± 7,5	50,32 ± 4,5
After 3 months	50,40 ± 7,7	51,86 ± 3,8
After 8 months	52,17 ± 7,8	53,31 ± 4,1
p-level	X = 73,6 p = 0,0000 sig	X = 60,8 p = 0,0000 sig

p(Friedman ANOVA and Kendall)

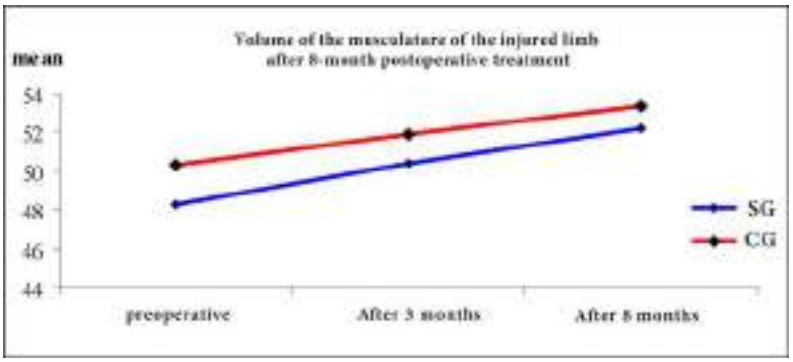

Figure 5: Line diagram for the extent of muscle injuries for the period of the study – SG and CG

Discussion

In our case, after the preoperative measurement of the thigh muscle volume of the injured limb, in the SG it was 48.22 ± 3.5 cm on average, while in the CG the thigh muscle volume of the injured limb showed an average result of 50.32 ± 4.5 cm.

Statistically, we obtained a result (p = 0.13) that indicates a non-significant difference in terms of preoperative measurements between the two groups. The results we got after the analysis 3 months after the operative treatment, also in relation to the extent of the musculature of the injured limb, did not show a big difference. Both control groups had on average similar muscle circumference of the injured limb (50.40 ± 7.7 and 51.86 ± 3.8 cm, respectively). We got almost the same results after measurements carried out 8 months after operative treatment. The average of the muscle volume of the group treated only by sacrificing the semitendinosus muscle was 52.17 ± 7.8, 92 while from the group performed by sacrificing both hamstrings, we obtained a result of 53.31 ± 4.1 cm. This indicates that even 8 months after the operative treatment there is no significant difference in the volume of the muscles in both groups.

Michan B.Hebert at all made a research and compare the surgical lower limbs and the non-surgical lower limbs for differences in lean mass, thigh circumference, and the ability to balance during single leg stance. They compared lower limbs in individuals with ACL reconstruction surgery or injury and the lower limbs in a Control group.Data were collected from 12 ACL participants and 30 Control participants. In ACL participants, there were no significant differences between the thigh circumferences of the lower limbs at the 10 cm mark or the 15 cm mark (p = 0.247 and p = 0.266, respectively. There was a main effect difference in thigh circumference between the ACL and Control participants via ANOVA (F = 144.287, p < 0.0001). In Control participants, there was a significant difference at the 10 cm measurement mark in dominant lower limb thigh circumference compared to non-dominant lower limb thigh circumference (p = 0.040. There was no significant difference in thigh circumference at the 15 cm measurement mark in dominant lower limb compared to the non-dominant lower limb for Control participants (p = 0.243).[23]

Ahmet Serhat Genc made a retrospective cohort of 20 sedentary men who underwent the traditional ACLR (ST/G) technique. The retrospective cohort part of the study included only post-operative 6th month thigh and leg circumference measurements and proprioceptive sense measurements. All patients were referred to the same rehabilitation specialist and postoperative follow-up (6 months) was done. Inclusion criteria for this study were: (a) 18-35 years old, (b) have had Semitendinosus/Gracilis (Hamstring Autograft) anterior cruciate ligament reconstruction (ACLR), and c) have no other neuromuscular or musculoskeletal injury or a history of contralateral knee surgery or injury. Their 6th month post-operative results did not show a significance between operated and non-operated sides in patients who had undergone

ST/G ACLR operation. These results showed that thigh circumference, leg circumference and proprioceptive sense on operated side approached the healthy side in an average of 6 months, indicating a good rehabilitation process after ACLR and regeneration of ACL receptors [24].

Sholahuddin Rhatomy et all also made a prospective observational study of a consecutive study series of ACL reconstruction patients. Sixty-one patients underwent single-bundle ACL reconstruction from 2015 to 2017. Between October 2015 and June 2016, patients were allocated to ACL reconstruction with a hamstring tendon, while, between July 2016 and February 2017, the peroneus longus tendon was used.In the peroneus longus tendon group, no patients had thigh hypotrophy of more than 20mm, only one patient had thigh hypotrophy of 20mm and four patients had thigh hypotrophy of 10mm,. Thigh hypotrophy was significantly greater in the hamstring tendon group 1 year after the surgery ($p = 0.002$). The hamstring group showed a mean decrease in donor thigh circumference of 11.4 ± 3.6mm, compared with the peroneus longus group, with a mean thigh circumference difference of 2.5 ± 0.5mm [25].

However, after all the analyses performed in this study and after monitoring the volume of the musculature in all the subjects, it was observed that the patients who are occupied with active sports have better results.

Conclusion

In our study, after the evaluation and the analysis of the volume of the thigh muscles in the preoperative period and in the period after 3 and 8 months after the operative treatment, in our subjects, we have shown a positive outcome from the implementation of this technique. The statistical analysis after the measurements made in the period of 3 and 8 months after the operative treatment did not show a significant difference between the performed surgical techniques, but still showed us a significant increase in the volume of the upper leg in both groups. The volume of the thigh muscles of the injured limb increased significantly during the follow-up period in both groups of patients. In SG, the average volume increase was registered of the thigh muscles at the end of the follow-up compared to the preoperative values by 8.2%, while this increase in CG was 5.9%.

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