



Isokinetic Exercises in Quadriceps Strength and Endurance Recovery After Anterior Cruciate Ligament Reconstruction

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Abstract

Background/Aim: Muscle strength and endurance recovery of the quadriceps after anterior cruciate ligament reconstruction is necessary for normal knee function. In addition to the use of the isokinetic dynamometer for diagnostic purposes, its possible therapeutic effect is also important, ie targeted correction of the measured muscle deficit. This work was aimed to examine the level of quadriceps strength and endurance recovery 6 months after the anterior cruciate ligament reconstruction in patients who performed isokinetic training and to determine whether it is a superior therapeutic intervention compared to isodynamic training.

Methods: A total of 70 patients of both sexes were monitored in a prospective clinical study. Three months postoperatively, all patients had quadriceps torque measured to body weight on an isokinetic dynamometer at angular speeds of 60 and 180 °/s. Patients were divided into two groups according to the type of applied rehabilitation protocol. Group A patients (n = 35) underwent a rehabilitation program 5 times a week using an individual kinesitherapy program (isometric and isotonic exercises for quadriceps and hamstrings) and neuromuscular electrostimulation of the quadriceps. In addition patients from group B (n = 35) were included in targeted isokinetic exercises for the quadriceps. Control isokinetic testing was performed 6 months after surgery. The comparison of the effect of the applied therapeutic procedures in groups A and B was performed with the Student t-test (p < 0.05).

Results: An average age of patients was 27.29 ± 5.94 years. In patients in group B, statistically significantly higher values of the peak torque to body weight were measured at angular velocities of 60 and 180 °/s for the quadriceps of the operated knee 6 months after reconstruction of the anterior cruciate ligament with hamstring tendons (p < 0.05).

Conclusion: Isokinetic training achieved significantly better quadriceps strength and endurance in patients 6 months after anterior cruciate ligament reconstruction with hamstring tendons compared to dynamic exercises.

Key words: Quadriceps muscle; Rehabilitation; Anterior cruciate ligament reconstruction.

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Introduction

Reconstruction of the anterior cruciate ligament (ACL) is necessary to achieve restoration of anatomy and static stabilisation after its rupture.¹ The optimal rehabilitation programme after ACL

reconstruction is one of the most dynamic areas of research in rehabilitation.² In kinesitherapy, three types of therapeutic exercises are used: static, dynamic and isokinetic. The main differ-

ence between the mentioned types of therapeutic exercises is the state of muscle tone and the length of muscle fibres. During static exercise, muscle tone increases but the length of muscle fibres does not change. Dynamic exercise shortens muscle fibres during which muscle tone varies. Isokinetic exercise means exercising always at the same speed with variable resistance. In contrast to the dynamic exercise, where muscle work changes with the angle of action of the force, constant muscle work is achieved during isokinetic exercise.³ Bearing in mind this fact, isokinetic exercises provide the possibility of targeted correction of the measured deficit of muscle strength and endurance. However, for their performance,

isokinetic systems (dynamometers) are needed, which enable first the diagnosis of muscle performance deficits and later their targeted therapeutic correction. Because of high costs, these systems are often not available to all rehabilitation facilities.⁴

This work was aimed to determine the recovery of muscle strength and endurance of the quadriceps in patients 6 months after reconstruction of the ACL with hamstring tendons and to determine are isokinetic exercises a superior therapeutic intervention in the rehabilitation of these patients compared to dynamic exercises.

Methods

Patients of both sexes, after anterior cruciate ligament reconstruction using hamstring graft were included in a prospective clinical study. Three months postoperatively, all patients quadriceps peak torque to body weight were measured on the isokinetic dynamometer at the angular velocity of 60 and 180 °/s.

Table 1: Differences in applied rehabilitation program between patients in group A and B

Type of therapeutic intervention	Group A	Group B
Neuromuscular electrostimulation	+	+
Dynamic exercises	+	+
Isokinetic exercises	-	+

Group A – Patients rehabilitated using dynamic exercises

Group B- Patients rehabilitated using dynamic + isokinetic exercises

Patients were divided into two groups according to the type of applied rehabilitation protocol. Group A patients (n = 35) underwent a rehabilitation program 5 times a week using an individual kinesitherapy program (isometric and dynamic exercises for quadriceps and hamstrings) and neuromuscular electrostimulation of the quadriceps. Patients from group B (n = 35) were involved in targeted isokinetic exercises for the quadriceps (Table 1).

Control isokinetic testing was performed 6 months after surgery. The comparison of the effect of the applied therapeutic procedures between the groups A and B was performed with the Student's t-test. Level of statistical significance was set at $p < 0.05$.

Results

A total of 70 patients of both sexes (predominately male), with an average age of 27.32 ± 2.21 years were included in the study (Table 2).

Table 2: General characteristics of the examined sample

Group	N	Gender		Age (Mean \pm SD)	p-value
		Male	Female		
Group A	35	31	4	27.21 ± 1.45	$p = 0.62$
Group B	35	29	6	27.43 ± 2.97	$p = 0.75$
Total	70	60	10	27.32 ± 2.21	$p = 0.69$

Group A – Patients rehabilitated using dynamic exercises

Group B- Patients rehabilitated using dynamic + isokinetic exercises

Sixth month after ACL reconstruction significantly higher values of peak torque to body weight at the angular velocity 60 °/s were measured in patients from group B ($t = 7.19$, $p < 0.05$) (Table 3).

The same results were recorded by monitoring the quadriceps peak torque to body weight at angular velocity 180 °/s in patients from group B ($t = 2.08$, $p < 0.05$) six months after ACL reconstruction (Table 4).

Table 3: Mean values of quadriceps peak torque to body weight at angular velocity 60 °/s in patients of group A and group B (3 and 6 month after the anterior cruciate ligament (ACL) reconstruction)

Examination	Group A		Deficit (Mean %)	Group B		Deficit (Mean %)
	Peak torque to body weight (Nm) Non-operated leg	Peak torque to body weight (Nm) Operated leg		Peak torque to body weight (Nm) Non-operated leg	Peak torque to body weight (Nm) Operated leg	
3 months postoperatively	299.5	218.2	27.15	300.3	222.4	25.94
6 months postoperatively	300.4	240.5	19.94*	310.7	268.5	13.58*

Student's t-test * $p < 0.05$

Group A – Patients rehabilitated using dynamic exercises

Group B- Patients rehabilitated using dynamic + isokinetic exercises

Table 4: Mean values of quadriceps peak torque to body weight at angular velocity 180°/s in patients of group A and group B (3 and 6 month after anterior cruciate ligament (ACL) reconstruction)

Examination	Group A		Deficit (Mean %)	Group B		Deficit (Mean %)
	Peak torque to body weight (Nm) Non-operated leg	Peak torque to body weight (Nm) Operated leg		Peak torque to body weight (Nm) Non-operated leg	Peak torque to body weight (Nm) Operated leg	
3 months postoperatively	212.1	208.2	1.84	214.3	209.4	2.29
6 months postoperatively	221.5	211.5	4.52*	231.6	223.7	3.45*

Student's t-test * $p < 0.05$

Group A – Patients rehabilitated using dynamic exercises

Group B- Patients rehabilitated using dynamic + isokinetic exercises

Discussion

Rupture of the ACL causes instability, which is a potential cause of secondary damage to other structures in the knee, which may lead to the earlier development of osteoarthritis.⁵ The dynamic stability of the knees, which is achieved by adequate strength of the muscles of the upper legs and their mutual balance, is the task of postoperative rehabilitation.⁶ It is crucial for the secondary prevention of re-injuries to the operated knee.⁷

To know what type of therapeutic exercise should be applied and in what dose (level of load, duration of the exercise, duration of the break between exercises and the total number of repetitions), it is necessary to make an objective assessment of the state of muscle performance (strength, power, work, endurance) of the targeted muscle groups that will be treated. After the standardised measurement methodology on isokinetic dynamometers, a report in written form for each examinee was obtained. This report contained parameters

of strength (peak torque, peak torque to body weight), power (average power), work (average work), endurance and the classic agonist/antagonist ratio. The advantages of this method of measuring quadriceps and hamstrings muscle performance are an objective insight into the condition of the tested musculature, the possibility of prescribing a targeted kinesitherapy program, repeatability of measurements and the possibility of comparison in terms of assessing the effectiveness of the prescribed therapy.⁸

Therefore, respecting the physiology of graft healing and applying different types of therapeutic exercises in different phases after ACL reconstruction, it is necessary to strengthen the knee flexors and extensors, improve their endurance and adequately balance them biomechanically.⁹

In the last ten years, a lot of research has been done in the field of muscle recovery of the thigh mus-

cles after ACL reconstruction.¹⁰⁻¹⁴ Although the relationship between quadriceps strength and the functional status of the knee has been controversial for some time, evidence has been found that a strong quadriceps stabilises the knee joint during walking and all other activities of daily living in patients after the ACL rupture.¹⁵ After the rupture of this ligament, the strength of the quadriceps is reduced to a greater extent compared to the hamstrings due to the neuromuscular imbalance caused by damage to the proprioceptive elements and adaptation to the phenomenon of “avoiding the quadriceps” during walking.¹⁶

This research dealt with the influence of isokinetic exercises on the degree of recovery of muscle strength and strength of the lower leg musculature 6 months after the reconstruction of the ACL. In patients from group A who were rehabilitated without isokinetic exercises, significantly weaker quadriceps strength was found, compared to the patients from group B. Looking at the postoperative results for the assessment of quadriceps strength at an angular velocity of 60 °/s, significant differences were found in patients from both examined group in the sixth postoperative month after ACL reconstruction, but this improvement was statistically more significant in subjects from the group B.

A group of German researchers reported similar results. Kline et al proved that the torque value of the quadriceps force at an angular velocity of 60 °/s 6 months after the reconstruction of the ACL with a patellar graft was significantly lower than expected and that the return to sports activities could not be recommended to the patients who participated in this research.¹⁷ One of the causes of this discrepancy between results in this paper and the mentioned study is certainly the difference in the choice of graft and consequently the type of applied postoperative rehabilitation protocol.

Li et al studied the effect of a moderated rehabilitation protocol lasting 12 weeks and determined by isokinetic measurement that there was no significant improvement in quadriceps strength 3 months postoperatively in patients from the examined sample. This result positively correlates with the results of this research.¹⁸

Researchers from Poland also proved the positive effect of isokinetic exercises that were carried out as part of the rehabilitation program in 16 - 24 postoperative weeks, which was reflected in a significant improvement in the value of the quadriceps force torque at an angular speed of 60 °/s.¹⁹

Torque of force versus body weight for the quadriceps at an angular velocity of 180 °/s is, in fact, an indicator of quadriceps endurance. Mikkelsen et al showed that good quadriceps strength and endurance helped patients return to pre-injury activity levels more quickly.²⁰

This study showed that group B patients who underwent postoperative rehabilitation using a combined rehabilitation protocol had significantly better values of quadriceps force torque at an angular velocity of 180 °/s 6 months after ACL reconstruction than patients who were rehabilitated using dynamic exercises.

Numerous studies confirm these facts because quadriceps weakness after ACL reconstruction is a well-documented area.^{21,22} Authors have not found studies that refute the results of this research.

Conclusion

Isokinetic training achieved significantly better quadriceps strength and endurance in patients 6 months after anterior cruciate ligament reconstruction with hamstring tendons, compared to dynamic exercises.

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Conflict of interest

None.

References

- Risvas K, Stanev D, Benos L, Filip K, Tsaopoulos D, Moustakas K. Evaluation of anterior cruciate ligament surgical reconstruction through finite element analysis. *Sci Rep* 2022 May 16;12(1):8044. doi: 10.1038/s41598-022-11601-1.
- Cavanaugh JT, Powers M. ACL Rehabilitation progression: where are we now? *Curr Rev Musculoskelet Med* 2017 Sep;10(3):289-96.
- Bielecki JE, Tadi P. Therapeutic exercise. [Updated: 4-Jul-2022]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan. [Cited: 1-Dec-2022]. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK555914/>.
- Dragičević-Cvjetković D, Bijeljac S, Palija S, Talić G, Nožica Radulović T, Kosanović Glogovac M, et al. Isokinetic testing in evaluation rehabilitation outcome after ACL reconstruction. *Med Arch* 2015;69(1):21-3.
- Jacob KM, Oommen AT. A retrospective analysis of risk factors for meniscal co-morbidities in anterior cruciate ligament injuries. *Indian J Orthop* 2012;46(5):566-9.
- Dragičević-Cvjetković D. [Outcome of rehabilitation after ligamentoplasty of the anterior cruciform ligament of the knee] [MSc thesis]. 2014. Banja Luka: Faculty of Medicine University of Banja Luka; 2014. Serbian.
- Wetters N, Weber AE, Wuerz TH, Schub DL, Mandelbaum BR. Mechanism of injury and risk factors for anterior cruciate ligament injury. *Oper Tech Sports Med* 2016;24(1):2-6.
- Weaver A, Roman D, Mosha M, Giampetruzzi N. Early strength testing after ACL reconstruction impacts isokinetic strength performance at time of return to sport. *Orthop J Sports Med* 2021;9(7 Suppl 3). doi:10.1177/2325967121S00119.
- Rousseu R, Labruyere C, Kajetanek C, Deschamps O, Makridis K, Djian P. Complication after ACL reconstruction and their relation to the type of graft: A prospective study of 958 cases. *Am J Sports Med* 2019;47(11):2543-9.
- Noll S, Garrison C, Bothwell J, Convey J. Knee extension range of motion at 4 weeks is related to knee extension loss at 12 weeks after anterior cruciate ligament reconstruction. *Orthop J Sports Med* 2015;3(5):23-9.
- Novaretti JV, Franciozi CE, Forgas A, Sasaki PH, Ingham S, Abdalla RJ. Quadriceps strength deficit at 6 months after ACL reconstruction does not predict return to preinjury sports level. *Sports Health* 2018;10(3):266-71.
- Krishnan C, Williams G. Factors explaining chronic knee extensor strength deficits after ACL reconstruction. *J Orthop Res* 2011;29(5):633-40.
- Kwok CS, Harrison T, Servant C. The optimal timing for ACL reconstruction with respect to the risk of postoperative stiffness. *Arthroscopy* 2013;29(3):556-65.
- Leporace G, Metsavath L, de Oliviera LP, Nadal J, Batisa LA. Motor coordination during gait after anterior cruciate ligament injury: a systematic review of the literature. *Rev Bras Ortop* 2013;48(4):293-9.
- Arhos EK, Thoma LM, Grindem H, Logerstedt D, Risberg MA, Snyder-Mackler L. Association of quadriceps strength symmetry and surgical status with clinical osteoarthritis five years after anterior cruciate ligament rupture. *Arthritis Care Res (Hoboken)* 2022 Mar;74(3):386-91.
- Eitzen I, Grindem H, Nilstad A, Moksnes H, Risberg MA. Quantifying quadriceps muscle strength in patients with ACL injury, focal cartilage lesions and degenerative meniscus tears: differences and clinical implications. *Orthop J Sports Med* 2016 Oct 11;4(10):2325967116667717. doi: 10.1177/2325967116667717.
- Czamara A, Tomaszewski W, Bober T, Lubarski B. The effect of physiotherapy on knee joint extensor and flexor muscle strength after anterior cruciate ligament reconstruction using hamstring tendon. *Med Sci Monit* 2011 Jan;17(1):CR35-41. doi: 10.12659/msm.881327.
- Lee OS, Lee YS. Changes in hamstring strength after anterior cruciate ligament reconstruction with hamstring autograft and posterior cruciate ligament reconstruction with tibialis allograft. *Knee Surg Relat Res* 2020 Jun 5;32(1):27. doi: 10.1186/s43019-020-00047-2.
- Markström JL, Grip H, Schelin L, Häger CK. Dynamic knee control and movement strategies in athletes and non-athletes in side hops: Implications for knee injury. *Scand J MedSci Sports* 2019 Aug;29(8):1181-9.
- Lieber RL, Silva PD, Daniel DM. Equal effectiveness of electrical and volitional strength training for quadriceps femoris muscles after anterior cruciate ligament surgery. *J Orthop Res* 1996 Jan;14(1):131-8.
- Suijkerbuijk MAM, Reijman M, Lodewijks SJ, Punt J, Meuffels DE. Hamstring tendon regeneration after harvesting: a systematic review. *Am J Sports Med* 2015 Oct;43(10):2591-8.
- Hunnicutt JL, McLeod MM, Slone HS, Gregory CM. Quadriceps neuromuscular and physical function after anterior cruciate ligament reconstruction. *J Athl Train* 2020 Mar;55(3):238-45.