Athens Institute for Education and Research
ATINER

ATINER's Conference Paper Series
FIT2013-0607

Isokinetic Evaluation and Objective Stability of the Knee after Anterior Cruciate Ligament Reconstruction

Matjaz Sajovic
Assistant Professor, Deputy Head of Orthopaedics and Sports Trauma Surgery Department, General Teaching Hospital Celje, Slovenia

Katarina Skaza
Physiotherapist, UNIOR d.d. Unitur Spa and Rehabilitation Center Zreče,
Slovenia

Simona Pavlič Založnik
UNIOR d.d. Unitur Spa and Rehabilitation Center Zreče,
Slovenia

Athens Institute for Education and Research
8 Valaoritou Street, Kolonaki, 10671 Athens, Greece
Tel: + 30 210 3634210 Fax: + 30 210 3634209
Email: info@atiner.gr URL: www.atiner.gr
URL Conference Papers Series: www.atiner.gr/papers.htm

Printed in Athens, Greece by the Athens Institute for Education and Research.

ISSN **2241-2891**
21/10/2013

An Introduction to ATINER's Conference Paper Series

ATINER started to publish this conference papers series in 2012. It includes only the papers submitted for publication after they were presented at one of the conferences organized by our Institute every year. The papers published in the series have not been refereed and are published as they were submitted by the author. The series serves two purposes. First, we want to disseminate the information as fast as possible. Second, by doing so, the authors can receive comments useful to revise their papers before they are considered for publication in one of ATINER's books, following our standard procedures of a blind review.

Dr. Gregory T. Papanikos
President
Athens Institute for Education and Research

This paper should be cited as follows:

Sajovic, M., Skaza, K. and Pavlič Založnik, S. (2013) **"Isokinetic Evaluation and Objective Stability of the Knee after Anterior Cruciate Ligament Reconstruction"** Athens: ATINER'S Conference Paper Series, No: FIT2013-0607.

Isokinetic Evaluation and Objective Stability of the Knee after Anterior Cruciate Ligament Reconstruction

Matjaz Sajovic
Assistant Professor, Deputy Head of Orthopaedics and Sports Trauma Surgery Department, General Teaching Hospital Celje, Slovenia

Katarina Skaza
Physiotherapist, UNIOR d.d. Unitur Spa and Rehabilitation Center Zreče, Slovenia

Simona Pavlič Založnik
UNIOR d.d. Unitur Spa and Rehabilitation Center Zreče, Slovenia

Abstract

Background: The most frequently used grafts for intra-articular anterior cruciate ligament reconstruction are the autologous patellar tendon or doubled semitendinosus and gracilis tendons autografts. There are still controversies about graft selection for primary anterior cruciate ligament reconstruction. Prospective, comparative studies are needed to determine the differences between the graft materials.

Methods: A prospective, comparative study was conducted on 80 consecutive patients who underwent arthroscopically assisted anterior cruciate ligament reconstruction between January 2010 and October 2011. All procedures were performed by the first author (M.S.). In 40 patients ACL reconstruction was performed with hamstring tendon autograft (STG group), and in the other 40 patients the reconstruction was performed with patellar tendon autograft (PT group). At 6 months follow-up, all patients have performed the isokinetic extensor and flexor muscles strength and KT-1000 measurements.

Results: In the STG group, the average deficit of peak extensor torque at angular velocity of 60°/s was 13.1%. The average peak flexor torque of the involved leg in the STG group was almost 95 % of peak flexor torque of the uninvolved leg. In the PT group, the average deficit of peak extensor torque was 25.2 %, and the average deficit of peak flexor torque was minimal (1.9 %). We found a statistical significant difference between the two groups in the extensor muscles power, while we did not find any statistical significant difference in flexor muscles power. There was no significant difference between the groups with respect to the objective stability of the reconstructed knee. At 6 months´ follow-up, the manual maximum KT-1000 arthrometer side-to-side difference was 0.9 ± 1.3 mm for the PT group and 1.2 ± 1.2 mm for the STG group (P = . 398).

Conclusion: At 6 months after surgery, we found significantly lower isokinetic quadriceps peak torque in the PT group compared with the STG group at angular velocity of 60°/s (Power test). We did not find significant differences in knee laxity measurements between the two study groups. The patients may return to sports 4 to 6 months postoperatively, but with the risk of reinjuring the knee.

Keywords: anterior cruciate ligament (ACL) reconstruction; hamstring tendons (STG) autograft; patellar tendon (PT) autograft; isokinetic muscle strength; knee laxity; short-term clinical

Corresponding Author: Matjaz Sajovic, Assistant Professor, Deputy Head of Orthopaedics and Sports Trauma Surgery Department, General Teaching Hospital Celje, Slovenia, matjaz.sajovic@triera.net

Introduction

The anterior cruciate ligament (ACL) rupture is the most common serious injury of the knee. Several risk factors for tearing the ACL have been evaluated in the literature. The highest incidence is in individuals 15 to 25 years old who participate in pivoting sports. 70% of ACL injuries occur in non-contact situations such as landing and cutting in sports. The risk factors for non-contact ACL injuries fall into four distinct categories: environmental, anatomic, hormonal, and biomechanical. Inadequate or compromised conditioning, experience, muscle recruitment patterns, and proprioception have been described as partially controllable, trainable characteristic. It is widely believed that knee injury with associated ACL tear may lead to functional instability. In the active sporting population, such instability has been found to be associated with muscle weakness, meniscal and chondral injuries as well as with the development of degenerative disease within the joint. (13, 17) The goals of ACL reconstruction are to decrease symptoms, improve function, and return patients to their pre-injury level of activity in the short term. ACL reconstruction is a common procedure that usually allows predictable and timely return to function for the patient. (14) It is customary now to allow return to full activities 6 months after the procedure, with some surgeons advocating return to sports as early as 4 months. (6)

A variety of graft sources, such as autografts, allografts, and synthetic grafts, have been used for ACL reconstruction. Because of numerous biologic advantages, the most frequently used grafts for intra-articular ACL reconstruction are the autologous patellar tendon (PT) or doubled semitendinosus and gracilis tendon (STG). Disadvantages of patellar tendon autograft are potential increase in patellofemoral pain and risk of persistent quadriceps muscle weakness. (3, 5, 11) Disadvantages of hamstring tendons (STG) autograft include potential hamstring muscle weakness and slower healing of the graft attachment site. (10, 12) Graft fixation is crucial in ACL reconstruction, and it is the weakest link in the initial 6 to 12 week period during which accelerated rehabilitation occurs. (14) Many questions have been raised as a result of accelerated rehabilitation program. One area of concern is that of muscle weakness of the involved extremity due to donor-site morbidity. (6) Second area of concern is objective stability of the reconstructed knee. Postoperative accelerated rehabilitation must prevent thigh muscle atrophy in the early postoperative period, but not compromise stability of the reconstructed knee.

The purpose of this study was to analyze objective stability and isokinetic strength of knee extensor and flexor muscles at 6 months after ACL reconstruction using two different autografts (PT versus STG) with identical fixation (interference screws) in consecutive patients undergoing the same accelerated rehabilitation program. The hypotheses of this study were: 1) there is significantly lower quadriceps muscle power in the PT group compared with the STG group 2) there is no significant difference in flexor muscle power comparing both groups 3) there are no significant differences in knee laxity measurements between the two study groups.

Methods

Patients

A prospective, comparative study was conducted on 80 consecutive patients who underwent arthroscopically assisted ACL reconstruction between January 2010 and October 2011. All procedures were performed by the first author (M.S.). The autografts used for ACL reconstruction were the central third PT and the STG graft. Patients were referred to a knee specialist without any selection bias and graft selection performed by surgeon was based on his individual preference. The inclusion criteria were the following: time from ACL injury to surgery less than 12 months, no previous ligamentous injury and surgery of either knee, no previous meniscal pathology treated with resection or repair, and no chondral lesions diagnosed by arthroscopy or MRI investigation. There were 40 patients in the STG group (35 men, 5 women, with a mean age of 29 years; range: 16-53 years) and 40 patients in the PT group (36 men, 4 women, with a mean age of 30 years; range: 19-42 years). Meniscal surgery were performed in 51% of patients in STG group and in 62% of patients in PT group (P = .408).

Surgical Technique

Apart from the graft harvesting the surgical technique was identical. All patients were examined under anesthesia (Lachman, drawer, pivot shift, and rotation tests were documented), after which routine diagnostic arthroscopy and meniscal surgery were performed, followed by the ACL reconstruction. The femoral tunnels were drilled at the posterolateral part, while the tibial tunnels were drilled through the central part of the anatomic footprints. The femoral tunnel was drilled through the anteromedial portal prior to tibial tunnel drilling. In the hamstring tendon group, the surgical procedure was an arthroscopic single-incision technique with double-looped semitendinosus and gracilis tendons. Drill guides were used to confirm the correct position of the tunnels. To find the femoral entry point, the author used the "bull's eye" drill guide (Linvatec, Largo, FL.). Tunnel size was matched to the cross-sectional size of the graft. A marking suture using No. 0 absorbable suture was set 2.5 cm from the femoral end of the graft to ensure good entry of the graft in the tunnel and to prevent the graft from twisting around the screw during insertion. The graft was inserted via the tibial tunnel into a blind femoral tunnel. The left thread or right thread round-head, cannulated interference screws (RCI, ART-MAM, Slovenia), was used for femoral graft fixation.(14) In right knees the screw with left thread was used and in left knees the screw with right thread was used. In right knee the left thread screw turns in left direction and pushes the transplant away from lateral wall of the intercondylar notch, and vice versa. This fact prevented graft impingement against the lateral wall of the intercondylar notch. Tibial anatomical joint line fixation was achieved by bioabsorbable interference screw (Linvatec) in an outside-in direction at a knee flexion angle of approximately 10° and manual pretension of the graft.

In the patellar tendon group, the surgical procedure was an arthroscopic single-incision technique with the central third of the ipsilateral bone-patellar-bone tendon used as a free autograft with matching drill tunnels made in the femur and tibia. The defects of the patella and the proximal tibia were not bone grafted. Tunnel size in the patellar tendon group was made 1 mm larger than the bone block size. The fixation of the graft in the drill tunnels was performed proximally with metal RCI screw and distally with bioabsorbable interference screw.

Average diameter of the bone tunnels in STG group was 8 mm (range, 7 to 9mm) while in PT group was 10mm (range, 9 to 11mm).

Postoperative Rehabilitation

All the patients were rehabilitated according to the same accelerated protocol, which permitted immediate full weight-bearing and full range of motion without use of rehabilitation brace. During the hospital stay (mean, 3 days), the focus was set on ROM, muscles control, and pain/ swelling management. The rehabilitation program has been completed in the Unitur Spa and Rehabilitation Center Zreče (Annex 1).

Evaluation

All measurements were performed at 3 and 6 months postoperatively in the Unitur Spa and Rehabilitation Center Zreče by the same senior physical therapist, which was directly involved in the patient's rehabilitation and not blinded to the type of surgery (Table 1). The isokinetic evaluation has been performed first and than followed with knee laxity measurements.

Isokinetic strength of the extensor and flexor muscle groups was measured with the isokinetic dynamometer En – Knee (Enraf – Nonius). The testing protocol was standardized to ensure reproducibility and validity. The patients were instructed on use of the isokinetic machine and allowed to become fully accustomed to the device before testing. They performed a 10-minute warm-up on stationary bicycle as well. The uninvolved leg was evaluated first, followed by the involved limb. The peak torque values of the isokinetic strength tests were measured, and than expressed as the difference between the involved and uninvolved limb.

Objective total AP knee laxity measurements were performed by using the KT-1000 arthrometer (MEDmetric, San Diego, CA). (15) The laxity data were recorded as the side-to-side difference in total AP tibial translation.

Statistical Analysis

The statistical data analysis was performed with SPSS. The analyzed variables were: gender, age, the average peak torque of the extensor and the flexor muscles of the leg and measurements of total AP displacement of the tibia. The level of statistical significance was determined with the value $P \leq .05$.

Results

Comparison of the isokinetic results among the two graft sources showed general similarities (Table 2). The average deficit of the Endurance test (3 months after ACL reconstruction) for extensor muscles in the STG group was 18.9 %. The average peak torque of the Endurance test for flexor muscles of the involved leg in the STG group was almost 95 % of the uninvolved leg. The average deficit of the Endurance test of extensor muscles in the PT group 3 months after ACL reconstruction was 21.7 %, and deficit of flexor muscles was minimal (3.7 %). Between the two groups we did not find any statistical significant difference.

All patients have performed isokinetic Power test at 6 months postoperatively. In the STG group, the average deficit of peak extensor torque was 13.1%. The average peak flexor torque of the involved leg in the STG group was almost 95 % of peak flexor torque of the uninvolved leg. In the PT group, the average deficit of peak extensor torque was 25.2 %, and the average deficit of peak flexor torque was minimal (1.9 %). We found a statistical significant difference between the two groups in the extensor muscles power, while we did not find any statistical significant difference in flexor muscles power.

There was no significant difference between the groups with respect to the objective stability of the reconstructed knee (Table 3). At 6 months´ follow-up, the manual maximum KT-1000 arthrometer side-to-side difference was 0.9 ± 1.3 mm for the patellar tendon group and 1.2 ± 1.2 mm for the hamstring tendon group (P = . 398).

Discussion

In a prospective, nonrandomized trial, we compared the use of the well-established and the most frequently used central third bone-patellar tendon-bone autograft (PT) with use of a doubled semitendinosus and gracilis tendon (STG) autograft. Apart from the graft, all other important factors for the clinical outcome, such as surgeon experience, fixation technique and the rehabilitation protocol, were identical. Numerous studies have recently been published comparing patellar and hamstring tendon autografts in arthroscopic ACL reconstruction. (1-6, 10, 11, 13, 14, 17) The present study continues to provide ongoing data showing the similarities and differences in the clinical results between the two groups. The results of our study substantiate the similarities found in previous reports that document that good or excellent results may be obtained in the majority of ACL reconstructions when using either PT or STG autografts. (1, 4) However, Bizzini et al. (5) reported significantly better results in the PT group.

Strength deficit, secondary to graft harvesting, has been one area cited as to why neither STG nor PT grafts have been the ideal solution for the ACL reconstruction. Many studies reported that the extensor muscle strength was significantly worse in the PT group (3, 10, 11, 12) and the flexor muscle strength was worse in the STG group. (3, 5, 11) With the increasing efforts to expedite the return not only of the athlete to the playing field, but also the worker back to productive employment, ACL rehabilitation programs have progressed substantially in the recent past. Studies in which more aggressive rehabilitation was permitted have demonstrated improved leg strength with both graft types during earlier rehabilitation period. Carter et al. (6) found no statistically significant differences between the groups in knee extension or flexion strength at angular velocity of 180°/s and 300°/s at 6 months postoperatively. Our isokinetic evaluation confirmed their results at angular velocity of 180°/s already at 3 months postoperatively. At 6 months postoperatively, we found significantly lower isokinetic quadriceps peak torque (percentage of the contralateral side) in the PT group compared with the STG group at angular velocity of 60°/s (Table 2). Regarding the fact that the measurements was performed at 6 months after ACL reconstruction the results were good as according to the literature the reduced extensor muscles strength (on average up to 10 %) is a normal phenomenon after ACL reconstruction (5, 7, 10) and that it can improve for several years after the surgery. (8)

Lautamies et al. (10) recorded, even 5 years after the ACL reconstruction the subjects had significant weaker thigh muscle strength in the involved leg compared with the uninvolved one. The reasons for bad results could be in irreversible preoperative tight muscle atrophy, inadequate operative therapy or/ and inappropriate postoperative rehabilitation. The thigh muscles strength reduction is also influenced by the time from injury to surgery. Due to the consequently unstable joint the functional ability of knee joint is reduced, which leads to long term weakness in the leg muscles and compensation with the healthy extremity. (3) In our clinic the waiting time for ACL reconstruction is very long and preoperative rehabilitation programs are inhomogeneous, therefore, the ignorance of this factor can be the reason for the significant difference in extensor muscle strength at 6 months postoperatively. The reason for the reduced thigh muscles strength can also be the fact that the injury itself and the operation initiate changes in the neurocentral sensory apparatus, which can lead to changes in the neuromuscular activation of thigh muscles in comparison with the uninjured population. (16) One of the problems of ACL reconstruction with use of the patellar tendon autograft is the presence of postoperative anterior knee pain (3) and the increased possibility of patellar dysfunction (2).

Our accelerated rehabilitation protocol is focused on immediate postoperative passive and active extension of the knee and muscles activation of the whole leg. Full weight-bearing without using the brace enables rapid restoration of physiological walk and thus prevents development of leg muscles atrophy. The early stages of rehabilitation take place under the expert supervision of a surgeon and it includes 14-day rehabilitation in the Rehabilitation Centre, where patients are instructed carefully on the proper way of doing exercises and gradual increase of activities. In the late stage of rehabilitation, there is less physiotherapy control, however, patients are motivated to participate in objective testing at 3 and 6 months after the surgery. The advantage of our research is in the fact that all subjects were operated by the same surgeon (M.S.) and the rehabilitation process was led by the same physiotherapist (K.S.). This is relatively rare in researching and represents a priority over research where more experts are included (7). Based on the results we can confirm the effectiveness of the whole rehabilitation protocol. Despite the fact that the accelerated rehabilitation protocol was identical for both groups, the extensor muscle strength was significantly worse in the PT group.

Considering the flexor muscle strength, measured at 3 months and at 6 months after surgery, the average deficit between the involved and the uninvolved leg was less than 6 % in both groups. This is a very good result, particularly in the STG group because previous research has found that the hamstring tendons harvest significantly reduces the flexor strength for approximately 1 to 2 years after surgery. (3, 5) Aune et al. (3) reported a significant difference in measurements of flexor muscle strength to the benefit of PT group. The results are justified with the presence of pain in the back of the knee and the reduced possibility of compensation of other muscles, especially the m. biceps femoris. Bizzini et al. (5) came to the same results where the cause for the difference was the trauma of flexor muscles during the surgery. The findings of our research do not confirm this. Excellent results resulted from good surgery technique of an experienced surgeon as well as rehabilitation program focusing on due and proper stretching and strengthening of flexor muscles.

Numerous studies reported that both hamstring and patellar tendon autografts provided good objective stability. (1, 3, 4, 11) In our study, there was no significant difference between the groups with respect to the objective stability of the reconstructed knee. At 6 months´ follow-up, the manual maximum KT-1000 arthrometer side-to-side difference was 0.9 ± 1.3 mm for the patellar tendon group and 1.2 ± 1.2 mm for the hamstring tendon group (*P* = . 398). However, Bizzini et al. (5) reported that the PT group reaching significantly better results.

The main limitations of our study are the nonrandomized protocol and small number of female patients who were included in our research. In order to obtain more reliable results, well-controlled, prospective long-term studies comparing patellar tendon with hamstring tendons autograft are needed.

Our study results showed that an appreciable quantity of patients had not regained adequate strength to be released to full sports activities without concern. In our opinion, the ACL-reconstructed leg should have 85% or greater return to the strength of the normal leg as one criterion before release to full sports activities. We were particularly intrigued to find only half of the competitive athletes had achieved this goal at 6 months after surgery.

Conclusion

The strength deficiencies found in our study concur with what has previously been shown in regard to ACL reconstruction. In addition, regardless of which graft is used, a considerable percentage of patients continue to have strength deficits. At 6 months after surgery, we found significantly lower isokinetic quadriceps peak torque in the PT group compared with the STG group at angular velocity of 60°/s (Power test). We did not find significant differences in knee laxity measurements between the two study groups. The patients may return to sports 4 to 6 months postoperatively, but with the risk of reinjuring the knee.

Annex 1 Our accelerated rehabilitation program

Necessary conditions for hospital discharge
Swelling and pain control
Full passive extension of the knee
Active ROM 0° to 90°
Good leg muscles control
Full weight-bearing without postoperative brace

Weeks 2 to 4 after surgery
Full passive and active extension
Active flexion up to 120^0 - 130^0
Physiological gait pattern
Prevention of muscle atrophy
Closed kinetic-chain exercises
Proprioception exercises

Weeks 5 to 8 after surgery
Full active ROM
Open kinetic-chain exercises
Muscle endurance exercises
Muscle power exercises
Isokinetic training
Advanced proprioception exercises
Coordination training

Weeks 8 to 12 after surgery
Muscle power training for all muscle groups with maximum load
Gradual explosiveness muscular contraction training
Outdoors cycling with maximum load

3 months after surgery isokinetic Endurance test is performed on the Biodex Pro 4 with angular velocity of 180°/s in the range of motion from 20^0 to 90^0

flexion in the knee, 25 repetitions. Based on the test results the patient is allowed to start with more complex functional activity.

Postoperative month 3 to 4
Muscle power gain of all muscle groups
Athletic training
Jumping activities
Avoiding forced rotational movements and uncontrolled jumps

Postoperative month 5 to 6
Muscle power gain of all muscle groups
Accelerated preparation to the full loads in sports
Sprints, shuttle run cutting maneuver, running with change in direction, eights
Sports specific training
At 6 months after surgery isokinetic Endurance and Power tests measurements, measurements with KT-1000 arthrometer and functional tests are performed. Based on the results of measurements the evaluation is given either patients are ready for full sports activity.

Table 1. *Isokinetic and knee laxity evaluations*

Endurance test	Power test	Total AP laxity
3 months postoperatively	6 months postoperatively	6 months postoperatively
angular velocity of 180°/s	angular velocity of 60°/s	KT- 1000 arthrometer
ROM 20°- 90°	ROM 10°- 90°	• 134 N • manual maximum force
25 repetitions	6 repetitions	average of three measurements

Table 2. *Group average deficit (%) and standard deviations (SD) for isokinetic strength measures comparing involved and uninvolved leg at 180^0/s and 60^0/s velocity and the level of statistical significance between the two groups*

		Group STG		Group PT		Statistical significance (STG/PT)
		Average deficit (%)	SD	Average deficit (%)	SD	
Endurance test 180^0/s	Extensor muscles	18.9	13.2	21.7	16.4	SI (*P* = .405)
	Flexor muscles	5.6	12.4	3.7	9.0	SI (*P* = .461)
Power test 60^0/s	Extensor muscles	13.1	10.4	25.2	15.3	**SS (*P* =.00015**)
	Flexor muscles	5.4	15.7	1.9	11,.4	SI (*P* = .494)

Legend: *P* - value of statistical significance
SI – statistically insignificant
SS – statistically significant

Table 3. *KT-1000 measurements with average differences, standard deviation (SD) and statistical significance for total AP laxity comparing two groups*

	KT-1000 measurements at 6 months postoperatively				
	Group STG		**Group PT**		**Statistical significance (STG/PT)**
	Average (mm)	SD	Average (mm)	SD	
134 N	1.1	1.5	0.8	1.6	SI (*P* =. 509)
Manual maximum	1.2	1.2	0.9	1.3	SI (*P* = . 398)

Legend: *P* - value of statistical significance
SI – statistically insignificant

References

Aglietti P, Giron F, Buzzi R, Biddau F, Sasso F. (2004) *Anterior cruciate ligament reconstruction: bone-patellar tendon-bone compared with double semitendinosus and gracilis tendon grafts. A prospective, randomized clinical trial.* J Bone Joint Surg Am. 86-A (10):2143-2155.

Anderson JL, Lamb SE, Barker KL, Davies S, Dodd CA, Beard DJ. (2002)*Changes in muscle torque following anterior cruciate ligament reconstruction: a comparison between hamstrings and patella tendon graft procedures on 45 patients.* Acta Orthop Scand. 73(5):546-552.

Aune AK, Holm I, Risberg MA, Jensen HK, Steen H. (2001) *Four-Strand Hamstring Tendon Autograft Compared with Patellar Tendon-Bone Autograft for*

Anterior Cruciate Ligament Reconstruction A Randomized Study with Two-Year Follow-Up. Am J Sports Med. 29(6):722-728.

Beard DJ, Anderson JL, Davies S, Price AJ, Dodd CAF. (2001) *Hamstrings vs. patella tendon for anterior cruciate ligament reconstruction: a randomized controlled trial.* The Knee. 8(1):45-50.

Bizzini M, Gorelick M, Munzinger U, Drobny T. (2006) *Joint Laxity and Isokinetic Thigh Muscle Strength Characteristics After Anterior Cruciate Ligament Reconstruction: Bone Patellar Tendon Bone Versus Quadrupled Hamstring Autografts.* Clinical Journal of Sport Medicine. 16(1):4-9.

Carter TR, Edinger S. (1999) *Isokinetic Evaluation of Anterior Cruciate Ligament Reconstruction: Hamstring Versus Patellar Tendon*. Arthroscopy 15(2):169-172.

Dauty M, Tortellier L, Rochcongar P. (2005) *Isokinetic and Anterior Cruciate Ligament Reconstruction with Hamstrings or Patella Tendon Graft: Analysis of Literature.* Int J Sports Med. 26(7):599-606.

Dvir Z (2004) *Isokinetics, Muscle Testing, Interpretation and Clinical Applications.* Churchill Livingstone, Edinburgh (second edition).

Hislop HJ, Perrine JJ (1967) *The isokinetic concept of exercise.* Physical Therapy 47(2):114-117.

Lautamies R, Harilainen A, Kettunen J, Sandelin J, Kujala UM. (2008) *Isokinetic quadriceps and hamstring muscle strength and knee function 5 years after anterior cruciate ligament reconstruction: comparison between bone-patellar tendon-bone and hamstring tendon autografts.* Knee Surg Sports Traumatol Arthrosc. 16(11):1009-1016.

Maletis GB, Cameron SL, Tengan JJ, Burchette RJ. (2007) *A Prospective Randomized Study of Anterior Cruciate Ligament Reconstruction A Comparison of Patellar Tendon and Quadruple-Strand Semitendinosus/Gracilis Tendons Fixed With Bioabsorbable Interference Screws*. Am J Sports Med. 35(3):384-394.

Rosenberg TD, Franklin JL, Baldwin GN, Nelson KA. (1992) *Extensor mechanism function after patellar tendon graft harvest for anterior cruciate ligament reconstruction*. Am J Sports Med. 20(5):519-525.

Sajovic M, Vengust V, Komadina R, Tavcar R, Skaza K. (2006) *A prospective, randomized comparison of semitendinosus and gracilis tendon versus patellar tendon autografts for anterior cruciate ligament reconstruction: five-year follow-up*. Am J Sports Med. 34(12):1933-1940.

Sajovic M, Strahovnik A, Dernovšek MZ, Skaza K. (2011) *Quality of life and clinical outcome comparison of semitendinosus and gracilis tendon versus patellar tendon autografts for anterior cruciate ligament reconstruction.* Am J Sports Med. 39 (10):2161-2169.

Vauhnik R, Turk Z, Pilih IA. (2005) *Intra-rater reliability of using KT 2000 compuKT for measuring anterior tibial translation.* Zdrav. Vest. 74(5):285-288.

Williams GN, Chmielewski T, Rudolph KS, Buchanan TS, Snyder-Mackler L. (2001) *Dynamic knee stability: current theory and implications for clinicians and scientists.* Journal of Orthopaedic and Sports Physical Therapy. 31(10):546-566.

Xergia SA, McClelland JA, Kvist J, Vasiliadis HS and Georgoulis AD. (2011) *The influence of graft choice on isokinetic muscle strength 4-24 months after anterior cruciate ligament reconstruction.* Knee Surg Sports Traumatol Arthrosc. 19(5):768-780.