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Effect of physiotherapy on the strength of tibial internal rotator muscles in males after anterior cruciate ligament reconstruction (ACLR)

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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Summary

Background: The goal of this study was to evaluate the effect of physiotherapy on the strength of muscles responsible for tibial internal rotation (IR) in male patients after anterior cruciate ligament reconstruction (ACLR) using autografts of the semitendinosus and gracilis muscles (STGR).

Material/Methods: Fifty-nine males were examined. The first group consisted of 19 patients subjected to 4-stage physiotherapy following ACLR. The second group consisted of 20 males without knee injuries. The third group consisted of 20 males who had not undergone systematic physiotherapy within the last 12 months following lower limb injuries. Moments of maximal strength (MMS), isometric torque (IT), and peak torque (PT) were measured under static and isokinetic conditions using the Humac Norm System. In the first group, IT measurements were performed during the 13th and 21st week of physiotherapy, while PT measurements were performed during the 16th and 21st weeks of physiotherapy following ACLR. In the control groups (II and III) the measurements were performed once.

Results: In the first group, the IT (13 weeks) and PT (16 weeks) values of internal tibial rotator muscles, obtained from the operated extremities were significantly lower than the values obtained from the uninvolved knees and the control group results. During the 21st week of physiotherapy, the results obtained for IT and PT in patients after ACLR were similar to the values obtained from the uninvolved knees and the results of the second group subjects.

Conclusions: The 21-week physiotherapy in ACLR patients favorably affected the PT values of tibial rotator muscles of the operated knees. In the third group, the IT values did not indicate a complete improvement after 12 months without systematic physiotherapy.

key words: **peak torque • shank rotators • isokinetics**

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BACKGROUND

Common knee joint injuries involve an anterior cruciate ligament (ACL) tear. The patients usually undergo conservative treatment and surgery [1–3]. Surgery involves ligament reconstruction using a central patellar ligament band graft of the bone tendon-bone (BTB) type, as well as grafts harvested from the semitendinosus and gracilis muscles (STGR) the Achilles tendon, the quadriceps muscle or artificial ligaments [4]. At present, anterior cruciate ligament reconstructions (ACLR) are performed increasingly often using autografts harvested from the semitendinosus and gracilis muscles [5,6]. Zelle et al. (2006) indicated that such surgical procedures may be effective and contribute to restoration of knee joint stability [7]. The material for the ACL graft is harvested from the muscles – semitendinosus (belonging to the hamstrings muscle group) and gracilis (belonging to the adductor muscles of the thigh) – and the grafts are usually harvested from operated limbs [8]. These muscles bend the knee joint and rotate the tibia on the femur. The semitendinosus and gracilis muscles bend and rotate the tibia internally on the femur [9]. Graft harvesting from these muscles for ACL reconstruction results in partial damage of these muscles [10]. Under such circumstances, the structure and volume of these muscle tendons change and muscle strength is impaired. Studies on peak torque (PT) of knee joint muscles, mainly in the sagittal plane in patients after ACL reconstruction, are plentiful [11]; however, papers reporting PT induced in patients after ACLR and affecting the knee joint in the transverse plane by tibial rotation on the femur are sparse [12,13].

The issue of PT in the muscles contributing to tibial rotation on the femur in patients after ACLR who underwent rehabilitation has caused us to pose a few questions. The first one concerns the PT results, obtained for different values of tibial rotation angle on the femur in the operated limbs compared to the results obtained in the control groups. Is it possible to restore the strength in muscles contributing to internal tibial rotation on the femur? If so, how long does it take given the fact that the graft was harvested from the semitendinosus and gracilis muscles? Is it true that a special physiotherapy program does not significantly contribute to the improvement of the PT values in muscles contributing to tibial rotation in patients after ACLR, because only the time after surgery is important?

The goal of this paper was to evaluate the effect of physiotherapeutic procedures on PT values in muscles responsible for internal tibial rotation under static and isokinetic conditions in patients after ACLR using STGR grafts.

MATERIAL AND METHODS

The study was carried out in the Center of Rehabilitation and Medical Education of the College of Physiotherapy in Wroclaw. The subjects provided signed informed consent prior to the study. The experiment was approved by the university Research Committee. Measurements were performed on 59 males under static and isokinetic conditions of the muscles contributing to internal and external tibial rotation. The subjects were divided into 3 groups.

Group I consisted of 19 males after endoscopic reconstruction of an isolated ACL tear (ACLR) by Mitek's method (JOHNSON & JOHNSON GATEWAY® Company) using the autografts of the semitendinosus and gracilis muscles [14]. The grafts were harvested from flexor tendons of the operated knee joint. Graft stabilization was performed by the Regidfix method. The first group of subjects underwent a 4-stage physiotherapeutic procedure [15]. Group II consisted of 20 males with no lower limb injuries. Group III consisted of 20 male amateur athletes, who had sustained lower limb injuries, on average 12 months prior to the study, but did not participate in systematic physiotherapy. Table 1 presents characteristics of the basic somatic features of the studied cohorts.

Measurement of the moments of maximal strength (MMS) – isometric torque (IT) in muscles responsible for tibial rotation on the femur under static conditions

After medical examination, Group I subjects and the controls obtained the orthopedist's consent to participate in the experiment. Each subject was informed about the purpose and course of the study prior to anamnesis. Before the measurements of IT (Nm) under static conditions and PT under isokinetic conditions, the subjects did a 12 minute warm-up on a cycloergometer with a constant velocity of 60 rpm. During the first 6 minutes a 50 watt (W) load was applied. Next, the load was increased every 2 minutes by 5–10 W.

The warm-up was followed by a 5 minute break. After that, IT values were measured in the muscles responsible for internal rotation of the crus towards the thigh and for alternant external rotation of the crus in both lower extremities; first the uninvolved limbs were studied in Groups I and III and next, the right legs were studied in Group II. IT measurements were taken under static conditions in 6 positions of the rotation angle of the crus towards the thigh, namely: 30°, 20°, 10°, during external rotation (ER) of the tibia, during neutral rotation (NR) with a 0° rotation angle, and next during a 10° and 25° internal rotation (IR) of the tibia. The knee joint was stabilized at 80° flexion. The angle of hip flexion was also 80°. The measurements were performed using Humac Norm Testing & Rehabilitation Systems [16]. The measurement system was calibrated. Isometric torque (IT) measurements were taken in the supine position. The dynamometer axis was positioned according to the anatomical rotation axis of the examined knee joint. The chair was adjusted and the cushion was used to support the patient's cervical spine. The patient was stabilized using an oblong belt stabilizing the lumbosacral spine at the level of anterior-superior iliac spines and a 4-point belt, buckled at the level of the fifth and sixth rib pairs. The examined knee was positioned at 80° flexion on a stabilizing support. The belt providing thigh stability was threaded through the lateral and the middle buckle of the seat at the level of the lower third of the thigh. The shank of the uninvolved leg hung beyond the chair edge. During strength measurement, the subjects had their arms crossed on the chest and the head leaned against the chair. The range of movement was determined in the examined extremity. The foot was placed in the sagittal plane, in line with the shank and the thigh. The angle between the foot and the shank was 90°. Examination in each position of the tibial rotation angle involved alternant maximal isometric tension (contractions) of the muscles contributing to internal and external tibial rotation. The subject started maximal isometric muscle contractions on the "start" signal and finished them on the "stop" signal. The

Table 1. Characteristics of the studied groups. Mean values (X), standard deviation (SD).

Material	Features	Age (years)	Body height (cm)	Body mass (kg)
Group I(n=19)	X	34.20	176.84	81.63
	SD	8.20	8.80	11.84
Group II(n=20)	X	27.15	180.80	79.05
	SD	7.23	4.67	8.10
Group III(n=20)	X	28.55	180.65	77.70
	SD	8.27	7.40	2.25

duration of a single contraction was 6 seconds. There were 45-second intervals between the contractions. On completion of the measurements in 1 position, the angle of tibial rotation was changed. The positions were changed automatically and the angles were in accordance with the preset position of tibial rotation on the femur. Patients from the first group were examined initially during the 13th week and during the 21st week of physiotherapy after ACLR. The second and third group subjects were examined only once. The IT of the muscles contributing to internal and external tibial rotations were measured separately for the right and left knees. There was a 2-minute interval between the first and the second measurement. The highest obtained IT values were selected separately for each examined muscle group and each measurement angle of the right and left knee.

Peak torque (PT) measurement under isokinetic conditions

PT values for the muscles contributing to tibial rotation on the femur were measured in the patients during the 16th and 21st week following ACLR. Such measurements were performed only once in the control groups (groups II and III). The measurements were preceded by a warm-up period. During the procedure, the subjects assumed the baseline position and the sequence of measurements for each knee was the same as under static conditions. The examination involved 2 series of concentric exercises performed by the subjects under isokinetic conditions of alternant internal and external tibial rotation with angular velocities of 60°/s and 180°/s. Each series was preceded by 1 trial repetition. The subjects started a series of exercises on the "start" command and finished on the "stop" command. The first series included 5 repetitions performed with an angular velocity of 60°/s. The series of exercises was followed by a 90-second interval. After that, the second series of exercises was performed involving 8 repetitions with an angular velocity of 180°/s. On completion of the PT measurement of 1 knee there was a 2-minute break to prepare the measuring apparatus and to allow the subjects to rest, and then the PT values of contralateral knee were measured.

Statistical analysis

The results were then statistically analyzed. The mean values (X) and standard deviation (SD) of the obtained variables were calculated. The difference between the IT and PT values of the operated and uninvolved limbs were calculated using a non-parametric Wilcoxon's signed rank test for dependent variables (groups). The between group differences in the IT and PT values were determined using the Mann-Whitney nonparametric U test for independent variables. Statistical significance was accepted at the level of $p<0.05$ [17].

The statistical analysis was carried out using a SPSS Statistics v.17 Multilanguage program.

Results

The first group of patients obtained significantly lower mean IT values from the muscles contributing to internal tibial rotation in all studied ranges of the measurement angle when compared to the uninvolved knees during the 13th week following reconstruction. Table 2 presents these differences. The significance level ranged from p=0.016 to p=0.001. During the 21st week following ACLR, an increase in IT values for the muscles to internal tibial rotation and, importantly, the results obtained from the operated limbs, were closer to those obtained from the uninvolved ones. No statistically significant differences of the studied parameter were noted (Table 2).

During the 21st week of physiotherapy the IT values of the muscles contributing to internal tibial rotation increased as compared to the results obtained during the 13th week after ACL reconstruction for each measurement angle. For 4 of the 6 positions of the measurement angle, the increase was statistically significant at a level from p=0.017 to p=0.045. Only with 10° and 20° of tibial external rotation did the increase in IT values of the muscles contributing to internal tibial rotation become statistically significant as presented in Table 3.

In the first group, during the 13th week after ACL, the mean IT values of the muscles contributing to external tibial rotation in the operated knees were lower compared to the values obtained for the uninvolved knees. However, only at 25° of external rotation was the difference statistically significant (p=0.05).

During the 21st week after ACLR (the second examination), the results obtained for the operated knees were similar to the values obtained for the same group of shank-rotating muscles in the involved knees. This time, no statistically significant differences were noted (Table 4).

During the 21st week following ACLR, no statistically significant differences were found between the IT values of the

Table 2. Comparison of the IT values (Nm) of the muscles contributing to internal tibial rotation in the operated and uninvolved knees during the 13th and 21st week following ACLR.

n=19	IT (Nm) the muscles contributing to internal tibial rotation in patients (Group I) after ACLR									
	13 week after ACLR (examination 1)					21 week after ACLR (examination 2)				
Tibial rotation angle°	Operated leg (Nm)		Uninvolved leg (Nm)			Operated leg (Nm)		Uninvolved leg (Nm)		
	X	SD	X	SD	p	X	SD	X	SD	p
RZ 30°	38.8	9.4	47.8	10.2	0.001	47.1	9.4	47.8	10.7	0.647
RZ 20°	35.7	9.8	41.1	9.1	0.009	42.3	9.0	42.4	10.2	0.984
RZ 10°	32.4	8.4	36.5	9.6	0.016	36.7	7.3	37.5	8.3	0.541
NR 0°	26.6	8.6	32.8	9.6	0.001	32.9	5.7	30.9	6.9	0.471
RW 10°	22.9	6.2	28.6	8.5	0.003	27.5	6.4	29.7	8.5	0.132
RW 25°	15.5	5.7	21.2	7.6	0.002	20.3	5.0	21.8	7.4	0.231

ER – external rotation; IR – internal rotation; NR – neutral rotation.

Table 3. Comparison of the IT values (Nm) of the muscles contributing to internal tibial rotation Between the 13th and 21st week after ACLR in group I.

Tibial rotation angle (°)	13 week after ACLR (examination 1)		21 week after ACLR (examination 2)		P
	X	SD	X	SD	
ER 30°	38.8	9.4	47.1	9.4	0.034
ER 20°	35.7	9.8	42.3	9.0	0.093
ER 10°	32.4	8.4	36.7	7.3	0.171
NR 0°	26.6	8.6	32.9	5.7	0.045
IR 10°	22.9	6.2	27.5	6.4	0.042
IR 25°	15.5	5.7	20.3	5.0	0.017

ER – external rotation; IR – internal rotation; NR – neutral rotation.

Table 4. Comparison of the IT values of the muscles contributing to external tibial rotation in the operated and uninvolved knees during the 13th and 21st week after ACLR.

n=19	IT (Nm) of the muscles contributing to external tibial rotation in group I – patients after ACLR									
	13 week after ACLR (examination 1)					21 week after ACLR (examination 2)				
Tibial rotation angle°	Operated leg (Nm)		Uninvolved leg (Nm)			Operated leg (Nm)		Uninvolved leg (Nm)		
	X	SD	X	SD	P	X	SD	X	SD	p
ER 30°	20.4	9.4	22.0	6.7	0.343	25.27	8.13	22.81	9.46	0.135
ER 20°	26.5	9.6	29.6	7.8	0.079	29.31	9.63	29.18	9.40	0.407
ER 10°	31.1	8.9	33.4	8.7	0.097	34.22	7.77	32.63	7.61	0.678
NR 0°	34.4	8.9	36.2	9.2	0.268	36.40	8.20	35.40	8.05	0.643
IR 10°	36.2	8.6	38.4	8.9	0.106	37.40	8.07	37.81	7.97	0.422
IR 25°	36.8	8.5	39.8	8.0	0.035	38.18	8.19	39.72	7.68	0.983

ER – external rotation; IR – internal rotation; NR – neutral rotation.

Table 5. Comparision of the values between the muscles contributing to internal and external tibial rotation in group I patients during 21st week following.

Tibial rotation angle (°)	IT of the muscles contributing to internal tibial rotation (Nm)					IT of the muscles contributing to external tibial rotation (Nm)				
	Group I 21st week after ACLR		Group II		p	Group I 21st week after ACLR		Group II		p
	X	SD	X	SD		X	SD	X	SD	
ER 30°	47.1	9.4	44.6	10.3	0.865	25.2	8.1	27.5	6.3	0.455
ER 20°	42.3	9.0	39.5	10.1	0.811	29.3	9.6	33.8	6.3	0.099
ER 10°	36.7	7.3	37.0	4.4	0.498	34.2	7.7	35.1	8.3	0.324
NR 0°	32.9	5.7	32.3	5.5	0.921	36.4	8.2	39.0	8.4	0.297
IR 10°	27.5	6.4	27.0	5.3	0.855	37.4	8.0	40.7	8.8	0.338
IR 25°	20.3	5.0	19.0	5.4	0.745	38.1	8.1	43.3	8.4	0.112

ER – external rotation; IR – internal rotation; NR – neutral rotation.

Table 6. Comparison of the IT values of the muscles contributing to tibial rotation during the 21st week after ACLR and the results obtained from group III subjects who did not participate in any systematic physiotherapeutic program.

Tibial rotation angle (°)	IT of the muscles contributing to internal tibial rotation (Nm)					IT of the muscles contributing to external tibial rotation (Nm)				
	Group I 21 week after ACLR		Group III		p	Group I 21 week after ACLR		Group III		p
	X	SD	X	SD		X	SD	X	SD	
ER 30°	47.1	9.4	38.2	12.1	0.054	25.2	8.1	23.6	8.1	0.121
ER 20°	42.3	9.0	32.5	10.5	0.014	29.3	9.6	29.2	9.2	0.324
ER 10°	36.7	7.3	27.5	7.7	0.005	34.2	7.7	34.1	11.2	0.349
NR 0°	32.9	5.7	25.5	8.9	0.002	36.4	8.2	34.8	10.6	0.757
IR 10°	27.5	6.4	20.1	6.4	0.004	37.4	8.0	36.3	10.9	0.978
IR 25°	20.3	5.0	14.0	4.8	0.001	38.1	8.1	40.1	13.2	0.391

ER – external rotation; IR – internal rotation; NR – neutral rotation.

muscles contributing to internal and external tibial rotation in the operated knees in patients after ACLR and the analogical values of the control groups (Table 5).

Group I (patients who underwent systematic physiotherapy after ACLR) obtained significantly higher IT values from the muscles contributing to internal tibial rotation during the 21st week of physiotherapy in 5 of 6 ranges of measurement angles as compared to Group III (patients who had sustained lower limb injuries, but did not participate in systematic physiotherapy). The significance level for the different angles of measurement ranged from p=0.014 to p=0.001 between the IT values of the muscles contributing to internal and external tibial rotation in different groups, as presented in Table 6.

In the first group of patients, a statistically significant increase was noted in the PT values obtained from the muscles contributing to internal tibial rotation in the operated knees under isokinetic conditions for both preset angular velocities, namely 180°/s and 60°/s (p=0.028 and p=0.037, respectively) during the 21st week following reconstruction when compared with the values obtained during the 16th week following reconstruction (Table 7). A statistically significant increase in the PT values obtained from the muscles contributing to external tibial rotation was noted (p=0.001 and p=0.002, respectively). Importantly, the results obtained from the operated leg during the 16th week following ACLR in the isokinetic test with a constant velocity of 180°/s were significantly lower than the results obtained from the uninvolved legs (p=0.005). The results obtained for the muscles contributing to internal tibial rotation in the patients during the 21st week following ACLR were similar to those obtained from the uninvolved legs, and no statistically significant differences were noted. A similar tendency, albeit at a higher level of the obtained PT values, was noted in the

Table 7. Comparison of the PT values of the muscles contributing to internal and external tibial rotation under isokinetic conditions in group I (patients) between the 16th and 21st week postoperatively.

Angular velocity °/s	PT internal tibial rotation (Nm) Group I – knee after ACLR		PT internal tibial rotation (Nm) Group I – uninvolved knee		p	PT external tibial rotation (Nm) Group I – knee after ACLR		PT external tibial rotation (Nm) Group I – uninvolved knee		p
	X	SD	X	SD		X	SD	X	SD	
180°/s – 16th week	27.05	5.93	30.33	4.52	p=0.005	26.88	5.84	28.16	4.66	p=0.119
180°/s – 21st week.	30.82	6.2	32.00	5.46	p=0.145	31.31	6.18	31.56	7.83	p=0.568
	p=0.028		p=0.130			p=0.001		p=0.046		
60°/s – 16th week	32.37	6.94	38.00	6.79	p=0.001	31.43	7.38	34.93	8.04	p=0.015
60°/s – 21st week	36.82	6.74	37.76	8.02	p=0.797	37.00	7.30	38.00	8.35	p=0.549
	p=0.037		p=0.659			p=0.002		p=0.055		

Table 8. Comparison of the PT values obtained from the muscles contributing to internal and external tibial rotation under isokinetic conditions between the operated limbs of group I patients during the 21st week after ACLR and the results obtained from group II and III.

Angular velocity°/s	Group I PT of the muscles contributing to internal tibial rotation of the operated leg		Control groups PT of the muscles contributing to internal tibial rotation		p	Group I PT of the muscles contributing to external tibial rotation of the operated leg		Control groups PT of the muscles contributing to external tibial rotation		p
	X	SD	X	SD		X	SD	X	SD	
180°/s – Group II	30.82	6.20	32.70	6.10	p=0.336	31.31	6.18	32.00	5.12	p=0.736
180°/s – Group III	30.82	6.20	28.61	5.71	p=0.380	31.31	6.18	30.50	5.27	p=0.577
60°/s – Group II	36.82	6.74	38.85	8.44	p=0.384	37.00	7.30	35.80	6.51	p=0.544
60°/s – Group III	36.82	6.74	33.78	6.58	p=0.135	37.00	7.30	34.33	6.81	p=0.261

isokinetic test performed with a velocity of 60°/s. During the 16th week of physiotherapy, the PT values obtained from the muscles contributing to internal tibial rotation in the operated legs were significantly lower (p=0.001) when compared to those obtained from the uninvolved legs. During the 21st week of physiotherapy, a statistically significant increase in the PT values was noted in the muscles of the operated knees and the results were similar to those obtained from the uninvolved legs. During the 21st week following ACLR, no statistically significant differences were noted between the results obtained from the operated and uninvolved legs (p=0.797) (Table 7). Analysis of the PT values obtained from the muscles contributing to external tibial rotation in the operated knees of patients from the first group revealed that with the angular velocity of 60°/s applied during the first measurement (16th week of physiotherapy) the values were significantly lower when compared to those obtained from the same muscle group in the uninvolved legs (p=0.015). The measurements performed during the 21st week of physiotherapy showed a significant increase in the values obtained from the operated knees, which were similar to the results obtained from the uninvolved legs. The examination carried out during the 21st week after ACLR did not reveal any significant differences between the results obtained from both legs (p=0.549) (Table 7).

Analysis of the results presented in Table 8 indicates that during the 21st week of physiotherapy the PT values obtained from the muscles contributing to internal and external tibial rotation were similar to the results of Group II subjects (males with no knee injuries), and did not reveal any statistically significant differences. A similar tendency was noted when we compared the results obtained from the above-mentioned muscle groups contributing to tibial rotation between Group I and Group III subjects. Subjects in the first group obtained higher PT values from the muscles contributing to internal and external tibial rotation in the operated knees for both preset angular velocities as compared to the Group III subjects; however, no statistically significant inter-group differences were noted (Table 8).

Discussion

Knee bending with internal and external tibial rotation is performed mainly by the muscles belonging to the ischiocrural muscle group and some posterior tibial muscles, particularly the triceps of the lower leg. The studied issue is essential as it pertains to the evaluation of the PT values obtained from the muscles contributing to internal tibial rotation in males participating in a 4-stage rehabilitation program after ACL reconstruction using grafts harvested from the semitendinosus and gracilis muscles. These muscles, when bending the knee, contribute to internal tibial rotation. We assumed that the procedure should contribute to changes in the PT ratios in muscles for internal (adverse) to external tibial rotation. As for this muscle group, we did not see any reason for substantial strength impairment. The results of our study confirmed this thesis; this was especially visible postoperatively during the 16th week. Ristanis et al (2009) reported a delay in bioelectric stimulation in ACLR patients at the side of graft harvesting, as revealed by electromyography [18].

Moreover, our literature review demonstrates that there are not enough studies dealing with this issue. In our study, we determined IT values of the studied muscle groups under static conditions for 6 angles of internal tibial rotation and 6 angles of external tibial rotation on the femur. The measurements ranged from 30 degrees of external rotation to 25 degrees of internal rotation of the tibia.

In the second group of males without ACL injuries we obtained IT values of muscles contributing to tibial rotation, depending on the angle of tibial rotation. The results were shaped as 2 parabolas, reflecting the different obtained by IT values depending on the measured joint angle and the studied muscle group contributing separately to internal and external tibial rotation. The values obtained for the uninvolved knees show a physiological pattern, which was the goal of the rehabilitation program for ACLR patients in terms of strength moments restoring in the above-mentioned muscle groups.

In the first group of ACLR patients, the measurements performed during the 13th week of physiotherapy under static conditions revealed significantly lower IT values of the muscles responsible for internal tibial rotation for most of the studied angles when compared to the uninvolved knees and the results obtained from the control group of males without knee injuries. Restoration of muscle strength may be achieved by alternant isometric and dynamic training with a high load and also with adequately selected level of intensity of exercise performance. However, during the first stage of physiotherapy, intensive training with a high load applied on hamstrings was contraindicated as time was needed to heal the site of graft harvesting from the tendons of the semitendinosus and gracilis muscles, affecting also the blood vessels and the surrounding soft tissues. Therefore, due to the above-mentioned biological conditioning, exercise with a partial load for the hamstrings was postoperatively introduced at the end of the sixth week. During subsequent weeks, the load and intensity were increased. During the exercise involving hamstrings, we tried to rotate the foot and lower leg internally, alternating with neutral rotation. In addition, concentric-eccentric exercises with an increased load were gradually introduced [15].

As a result, by the 21st postoperative week we had managed to restore baseline IT values of the muscles contributing to internal tibial rotation under isometric conditions for the 6 studied measurement angles. Moreover, the IT values obtained from the muscles contributing to internal tibial rotation at the site of the graft harvesting were significantly higher than the values obtained from the Group III subjects (males with lower limb injuries, who did not participate in systematic physiotherapy). We may assume that, apart from spontaneous healing of the graft harvesting site and its histologic reconstruction, the applied systematic, gradual rehabilitation program with an adequately selected load favorably affected IT restoration in ACLR patients. During the 21st week after ACLR, the IT values obtained from the muscle groups contributing to and the external internal tibial rotation in the operated knees were similar to the results obtained from the uninvolved knees under isokinetic conditions and to the results of the control groups, obtained for both preset angular velocities – 180°/s and 60°/s. The measurements were performed during concentric exercises with alternant internal and external tibial rotation [16]. The dynamics of changes in the PT values obtained under isokinetic conditions were lower when compared to the results of IT measurements taken under static conditions. These results were affected by the time of initiating the first measurements under isokinetic conditions (16th postoperative week) compared to the results obtained during the 13th week after reconstruction, performed under static conditions. It should be stressed that during the 13th week after ACLR a subsequent third stage of rehabilitation was started, involving exercise with increased load, intensity and difficulty [15]. The PT values and their increments, obtained under isokinetic conditions in ACLR patients between the first and second test for angular velocity of 180°/s, were lower compared to higher increments in this biomechanic parameter for angular velocities of 60°/s, and even lower values were obtained with 180°/s, compared to the results obtained under static conditions. The results and correlations are in agreement with Hill's equation determining the correlation between strength development and the speed of muscle shortening. In practice it means that the higher the preset angular velocity per second, the lower is the IT value of the studied muscle group and vice versa [19]. When evaluating the strength and strength-speed parameters in the process of complex treatment of ACL injuries, attention was paid to the decrease in IT values, obtained from the quadriceps muscle of the thigh and to the effect of this phenomenon on further treatment outcome. Obviously, the discussed issue is essential as it may affect the results of later treatment [20,21]. The studies dealing with the analysis of IT and relative strength moments

(RSM) obtained from knee extensor and flexor muscles after ACL reconstruction under static and isokinetic conditions are numerous [22–25]. Not only the relative values, but also the IT ratios for particular muscle groups and the correlations between the results obtained under static and isokinetic conditions, are essential in restoring strength in muscles affecting the operated joint [15,26]. Additionally, apart from isokinetic measurements, electromyography was performed in ACLR patients [27]. However, most of the studies evaluated changes in PT and the related values obtained in the sagittal plane. There have also been studies evaluating tibial rotation, mainly during passive motion, forced in tests using a robot model [28,29]. Moreover, tibial rotation was studied during a tridimensional gait analysis while performing complex specific rotations of the tibia on the femur in patients after 1- and 2-bundle ACL reconstruction [30]. Obviously, too few studies have been conducted so far to evaluate IT in muscles, which bend the shank in the sagittal plane contributing to tibial rotation. Popieluch et al. (2009) presented the results of IT in muscles contributing to tibial rotation before surgery, but did not report the changes resulting from IT generation during and after physiotherapeutic procedures [12]. Viola et al. (2000) noted a decrease in IT values in muscles contributing to internal tibial rotation on the femur in ACLR patients, finding that graft harvesting from the semitendinosus and gracilis muscles reduced the strength of these muscles when compared to analogous muscles of the uninvolved leg. The difference between the muscle strength in the operated and uninvolved leg was still noted postoperatively after 40–50 weeks [13].

Armour et al. (2004) evaluated the strength of muscles contributing to tibial rotation after 2 years following ACLR, using grafts harvested from the semitendinosus and gracilis muscles; the rotation was performed under isokinetic conditions with 60°/s, 120°/s and 180°/s. For all the preset angular velocities, the authors noted lower PT values in the muscles contributing to internal tibial rotation when compared to the uninvolved legs [31]. Our study results obtained from Group III (control group of males who sustained lower limb injuries on average 12 month before the study, and who did not participate in any systematic rehabilitation program) also indicated that the strength of the muscles contributing to internal tibial rotation was not fully restored. We wonder why the results of our measurements taken in the first group of ACLR patients differed so much from the results obtained by the above-cited authors and our results obtained from the third group.

Erikkson et al. (2001) found that 1 year after tendon graft harvesting for ACL reconstruction, the tendons partly regenerate [32]. Feretti et al. (2002) confirmed the features indicating regeneration and after 2 years – signs of advanced reconstruction at the site of graft harvesting [33]. Leis et al. (2003) carried out biomechanic examinations on semitendinosus muscles in rabbits, including resistance to stretching in the tendons where grafts were harvested – 16 weeks following the harvesting, the authors noted that the mechanical value of the harvested material reached 23% of healthy tendon quality, and within about 28 weeks following graft harvesting, it reached 68% of healthy tendon quality [34,35]. Histologic studies indicate that the healing process of graft harvesting sites takes some time.

Based on our study results and the literary review we can assume that healing process is extremely important. However, the healing alone, without a gradual and adequately performed rehabilitation program, cannot restore strength of these muscle groups in ACLR patients.

In order to verify our initial study results, we plan to continue the study on a larger sample.

Conclusions

1. Between the 13th and 21st weeks of systematic physiotherapy, there occurred strength improvement in muscles contributing to internal tibial rotation of the knees after ACL reconstruction.

2. At the 21st week of physiotherapy, the IT and PT values obtained under static and isokinetic conditions, respectively, in ACLR patients were similar to the values obtained from the uninvolved knees of patients and the results of the males with no lower limb injuries.

3. During the 21st week following ACLR, the patients obtained higher IT values in muscles contributing to internal tibial rotation in the operated knees when compared to the results of the males with lower limb injuries who did not participate in any systematic physiotherapy program.

References:

1. Musahl V, Jordan S, Colvin AC et al: Practice Patterns for Combined Anterior Cruciate Ligament and Meniscal Surgery in the United States. Am J Sports Med, 2010; 28: 918–23
2. De Loes M, Dahlstedt LJ, Thomee R: A 7-years study on risk and costs of knee injuries in male and female youth participants in 12 sports. Scan J Med Sci Sports, 2000; 10: 90–97
3. Boden BP, Griffin LY, Garret WE: Etiology and Prevention of Noncontact ACL Injury. Phys Sportsmed, 2008; 28: 4
4. Anterior Cruciate Ligament: Reconstruction and Basic Science. Ed. Prodromos Ch.C. Saunders, 2008
5. Duquin TR, Wind WM, Fineberg MS et al: Current Trends in Anterior Cruciate Ligament Reconstruction. J Knee Surg, 2009; 22: 7–12
6. Arnoczky SP: Anatomy of the Anterior Cruciate Ligament. Clinical Orthopaedics, 1983; 172: 19–25
7. Zelle B, Brucker PT, Feng TM, Fu HF. Anatomical Double-Bundle Anterior Cruciate Ligament Reconstruction. Sports Med, 2006; 36(2): 99–108
8. Zaricznyj B: Reconstruction of the anterior cruciate ligament of the knee using a doubled tendon graft. Clin Orhop Relat Res, 1987; (220): 162–75
9. Tixa S: Atlas d'anatomie palpatoire. Tome 2: Membre inerieur. Investigation manuelle de surface. Masson. Paris, 2005
10. Charalambous CP, Alvi F, Phaltankar P, Gagey O: Hamstring tendon harvesting on tendon characteristics and soft tissue disruption; cadaver study. Knee, 2009; 16(3): 183–86
11. Parisaux JM, Boileau P, Desneulle C, Berg M: Long term isokinetic evaluation of the knee flexor muscles after ACL reconstruction, using gracilis and semitendinosus tendon grafts. Isokinetics and Exercise Science, 2003; (11): 77–78
12. Popieluch M, Zieliński J, Jędrysik M: Evaluation of torque of the shank rotating muscles and the range of active internal and external rotation of the knee joint patients awaiting acl reconstruction. Human Movement, 2009; 10(2): 158–62
13. Viola RW, Sterlet WI, Newfield D et al: Internal and external tibia rotation strength after anterior cruciate ligament reconstruction using ipsilateral semitendinosus and gracilis tendon autograft. Am J Sports Med, 2000; 28(4): 562–65

14. Reconstruction ACL using Mitek's method *www.jnjgateway.com/commerce.* Johnson & Johnson Health Care Systems Inc., 2003–2004
15. 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; 17(1): CR33–41
16. CSMI User's Guide. Boston Massachussets, 2006
17. Starzyńska W: Podstawy statystyki. Podręcznik wydanie II. Wydawnictwo Difin 2009 [in Polish]
18. Ristanis S, Tsepis E, Giotis D et al: Electromechanical delay of the knee flexor muscles is impaired after harvesting hamstring tendons for anterior cruciate ligament reconstruction. Am J Sports Med, 2009; 37(11): 2179–86
19. Hill AV: Proceedings of the Royal Society of London. Series B, Biological Science, 1938; 126(843): 136–95
20. Eitzen I, Holm I, Risberg MA: Preoperative quadriceps strength is a significant predictor of knee function two years after anterior cruciate ligament reconstruction. Br J Sports Med, 2009; 43: 371–76
21. Czamara A: Evaluation of physiotherapeutic procedures after ACL reconstruction in males. Archives of Budo, 2010; 6(2): 1–9
22. Stefańska M, Rafalska M, Skrzek A: Functional asessment of knee muscles 13 weeks after anterior cruciate ligament reconstruction – pilot study. Ort Traum Reh, 2009; (11)2: 145–55
23. Czamara A: Functional benchmarking of rehabilitation outcomes following anterior cruciate ligament reconstruction. Ort Traum Reh, 2010; (6)6: 519–33
24. Czamara A: The atteration of the value of muscle forces in the programme of physiotherapy after the reconstruction of anterior cruciate ligaments. Pol J Phys, 2002; (2)4: 263–72
25. Czamara A: Functional benchmarks of musculoskeletal fitness following knee joint anterior cruciate ligament reconstruction. Pol J Phys, 2010; (10)4: 247–62
26. Urabe Y, Ochi M, Onari K: Changes in Isokinetic Muscle Strength of the Lower Extremity in Recreational Athletes with Anterior Cruciate Ligament Reconstruction. J Sport Rehabil, 2002; 11: 252–67
27. Mouraux D, Dugailly PM, Brassinne E, Vancabeke M: Randomized comparison of isokinetic dynamometry end electromyographic activity (sEMG) after anterior cruciate ligament reconstruction between semitendinosus and gracilis or patellar tendon autograft. Isokinetics and Exercise Science, 2005; 13: 18–19
28. Tsai AG, Musahl V, Steckel H et al: Rotational knee laxity: Reliability of a simple measurement device *in vivo*. BMC Musculoskeletal Disorders, 2008, 9: 35
29. Diermann N, Shchumacher T, Schanz S et al: Rotational instability of the knee: internal tibial rotation under simulated pivot shift test. Arch Orthop Trauma Surg, 2009; (129): 353–58
30. Tsarouhas A, Iosifidis M, Kotzamitelos D et al: Three-dimensional kinematic and kinetic analysis of knee rotational stability after single- and double-bundle anterior cruciate ligament reconstruction. Arthroscopy, 2010; 26(7): 885–93
31. Armour T, Forwell L, Litchfield R et al: Isokinetic evaluation of internal / external tibial rotation strength after the use of hamstring tendons for anterior cruciate ligament reconstruction. Am J Sports Med, 2004; 32(7): 1639–43
32. Ericsson K, Hmaberg P, Jansson E et al: Semitendinosus muscle in anterior cruciate ligament surgery: Morphology and function. Arthroscopy, 2001; 17(8): 808–17
33. Feretti A, Conteduca F, Morelli F, Masi V: Regeneration of the semitendinosus tendon after mit use in anterior cruciate ligament reconstruction. A histologic study of three cases. Am J Sports Med March, 2002; 30(2): 204–7
34. Leis HT, Sanders TG, Larsen KM et al: Hamstring regrowth following harvesting for ACL reconstruction: The lizard tail phenomenon. J Knee Surg, 2003; 16(3): 159–64
35. Kostka J, Kostka T, Czernicki J: Muscle strength, power, optimal shortening velocity and functional capacity of patients undergoing rehabilitation. Polish Journal of Sports Medicine, 2010; 26(5–6): 244–52

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