UDK 615.825:616.728.3-089.8 **Original Scientific Paper**
doi: 10.7251/SANUS2401043Z

ISOKINETICS IN KINESITHERAPY AFTER RECONSTRUCTION OF THE ANTERIOR CRUCIATE LIGAMENT

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Abstract. *One of the most common injuries in sports and recreation is an injury to the anterior cruciate ligament, and as a result of this injury, weakness of the thigh muscles and permanent disability of the knee may occur in a large number of cases. Although this topic has been extensively researched, there are still no uniform standards for the rehabilitation of these patients. The aim of this paper is to show and explain some of the benefits of isokinetic training in the rehabilitation of weakened muscles in patients after anterior cruciate ligament reconstruction. A retrospective study followed 180 male patients, three months after the reconstruction of the anterior cruciate ligament of the knee. The patients were divided into two examined groups according to the type of rehabilitation protocol they implemented. In group A-isokinetic, patients performed isokinetic exercise in kinesitherapy. Patients of group B-isotonic performed kinesitherapy based on standard exercises as part of the rehabilitation treatment, but with isotonic exercises. The protocols are designed to have a progression by days and weeks. The effect of rehabilitation was objectivized by an isokinetic test of the knee flexor muscles at an angular velocity of 60°/s before treatment, after three weeks and after six weeks of treatment. The examined parameter was the flexor torque of the operated leg - FLPTRQ (Nm). The monitoring period lasted for six weeks. Statistically significant differences ($p<0.05$) were found in the monitored parameter in both investigated groups, but in group A-isokinetic it was significantly higher after six weeks of treatment compared to group B-isotonic. The result of using isokinetic exercise is significantly better than the kinesitherapeutic result of exercise using a standard isotonic protocol. Based on the above, it is concluded that the isokinetic protocol is a more effective method in the restoration of the torque of the posterior thigh in patients after the reconstruction of the anterior cruciate ligament compared to the standard protocol.*

Key words: *isokinetics, anterior cruciate ligament, physiotherapy, rehabilitation.*

Introduction

Injury of the anterior cruciate ligament of the knee (ACL) has recently been on the rise among athletes and recreational sportsmen [1]. In the scientific literature, the term "sports knee" became popular. The injured person may have various symptoms and difficulties related to the knee, and usually these are discrete and hardly noticeable difficulties related to pain, swelling and limited movement, although sometimes more serious conditions may appear [2].

Growing economic factors in professional sports create ever-increasing demands placed on athletes with the goal of achieving top results, which in turn lead to exhaustion, overtraining, and often injuries. This is not the case only with active athletes, but recreationists are also exposed to injuries, as well as workers burdened with too difficult jobs, road users, so to speak, the entire population. Exposure of the locomotor system to large external and internal forces during sports activities is one of the many causes of injuries, and the most common are knee injuries. One of the most common injuries in sports and recreation is an injury to the anterior cruciate ligament of the knee, and as a result of these injuries, osteoarthritis and permanent damage to the thigh muscles can occur in a large number of cases [3,4,5].

Biomechanics and mechanism of injury

The ACL resists forward translation of the tibia, which is important for preventing hyperextension and ensuring knee stability during movement. To a lesser extent, it is responsible for the rotatory stability of the knee [6]. As the main stabilizer of the knee, it is thought to be responsible for as much as 85% of knee stability. Most ACL ruptures occur by non-contact mechanisms, a non-contact rotating injury where the tibia is translated forward, and the knee is slightly bent and in valgus [7]. A direct blow to the side of the knee is also represented as one of the mechanisms of injury. The most risky sports are skiing, football and basketball. Multiple intra-articular and extra-articular injuries may be associated with acute ACL ruptures. Among them are meniscal lacerations, an injury to the lateral meniscus in more than half of acute ACL tears, while the medial meniscus is more involved in chronic cases. Other knee ligaments and other structures associated with an ACL injury may also be injured. It seems that the consequences of an ACL injury have a harmful effect on the knee, with the development of chondral injuries and complex unhealed meniscal tears, more often the medial one [8], but also with the weakening of the thigh muscles, where the muscles of the hamstring play an important role [9]. Other risk factors that could increase the risk of injury include anatomic risk factors such as increased body mass index, smaller ACL, hypermobility, joint laxity, and previous ACL injury. Certain risk factors have been reported to be associated with certain sports, such as football and basketball [10].

Therapy

Surgical reconstruction

In young adults who wish to return to pre-injury activities, surgical reconstruction of a torn ACL is considered the "gold standard". Nonoperative treatment of ACL-injured knees has been proposed as an alternative in the past but has been associated with poor functional outcome. Nonoperative treatment resulted in poor functional results that prevented return to pre-injury activities in most patients, as well as an increased incidence of secondary ACL and meniscus surgery [11]. One randomized controlled study suggests that some patients with well-defined characteristic symptoms can be effectively treated nonoperatively [12]. It has been suggested that a structured rehabilitation program with optional ACL reconstruction at a later stage, if necessary, could have an outcome similar to earlier reconstruction [13]. In the technique of ACL reconstruction, there are several controversies that have involved orthopedic surgeons and researchers. It is about the time elapsed from injury to surgery and from surgery to rehabilitation, and about the type of graft used in the reconstruction itself. Regarding the type of surgical intervention, the description of the double bundle technique created expectations for the anatomical technique, but there is a dispute about the validity of this claim. There are three main factors to consider during ACL reconstruction. These are: increased incidence of meniscal and cartilage injuries after delayed ACL reconstruction, risk of arthrofibrosis after early ACL reconstruction, and morphological-functional damage of thigh muscles due to inactivity after delayed surgery and rehabilitation [14]. The two most commonly used autografts for ACL reconstruction are the patellar tendon (PT) (also known as the BPTB graft) and the hamstring tendon (HT). The general bias, as indicated by most case-control studies and meta-analyses, is that both grafts show excellent results with no differences between them in terms of functional outcome and level of mobility after surgery. However, there are also explicit advocates for each type of graft, and certain advantages and disadvantages for each type of graft are explained in the literature. Biomechanical data comparing PT and HT grafts with native ACL revealed that the PT graft had a peak load of 2730 N or 2900 N (depending on whether the midportion or endportion was tested) and a strength of approximately 57 MPa, suggesting that it is about 160-170% stronger and about 150% tighter than natural ACL [15].

Physical therapy and other physiotherapy procedures

Physical therapy includes treatment with physical agents, both natural and artificial ones. Damage to the ligamentous structures of the knee joint are pathological conditions in which physical agents can have multiple effects, in terms of analgesic therapy (for pain), promoting healing tissue or improving muscle tissue trophism during immobilization - as a prevention of hypotrophy. In the rehabilitation of patients after ACL reconstruction, several physical agents are used, namely:

Magnetotherapy stimulates osteogenesis by inducing a piezoelectric effect in the area of bone discontinuity, causing hypervascularization and promoting the deposition of calcium salts. Under the influence of the magnetic field in the protein crystalloid macromolecules, a positive piezoelectric effect occurs, which activates osteoblasts, chondroblasts and fibroblasts, so that the proliferation of bone, cartilage and connective tissue occurs.

The magnetic field causes the expansion of arterioles and capillaries, reduces blood viscosity and improves tissue oxygenation and metabolism. It also has an analgesic effect - suppresses pain.

When applied using a straight steam solenoid, the dose is up to 20 and more mT (mili Tesla) per solenoid. The therapeutic series consists of 15-20 sessions that usually last 30 minutes. If applied using a cylindrical solenoid, the dosage is lower, up to 10 mT [16].

Laser rays are partly reflected and a part of them penetrates the body when they fall on the skin. The ratio of reflected and penetrated rays depends on the incident angle and their wavelength. Penetration is greatest when the rays fall perpendicularly. Their effect is multiple - they stimulate tissue regeneration and have anti-edematous, analgesic and anti-inflammatory effects [16].

Interferential currents are amplitude modulated alternating sinusoidal currents of low modulation frequency that are created by crossing two medium frequency currents.
Interferential currents improve the reabsorption of swelling and promote tissue trophicity, because they cause the dilation of arterioles and capillaries and thus increase blood and lymph circulation. They also have an analgesic effect [16].

TENS or transcutaneous electronic nerve stimulation is a treatment aimed at reducing pain by stimulating certain nerve endings in the skin. By stimulating the skin receptors, the impulses go to the spinal cord via fast nerve fibers, where the so-called overriding of the impulse occurs, and thus the impulses that travel through the fast fibers eliminate the others. The frequency of TENS is up to 100 Hz and it is mostly used in all painful conditions where there are no contraindications for its use. It causes the secretion of endogenous opioids that have an analgesic effect [16].

Electrostimulation is a physical procedure by which we use electrical stimuli to cause muscle contraction. It is used for the purpose of muscle stimulation, muscle tone, development of muscle strength and muscle hypertrophy after injuries. More recently, it is also used for more successful muscle recovery after exercise [16, 17].

Kinesio taping is a physiotherapy method designed to relieve pain and accelerate the body's healing process by providing support and stability to muscles and joints. Kinesio taping does not limit the range of motion of the treated body parts, but increases that range of motion [18].

Proprioceptive neuromuscular facilitation (PNF) protects joints from excessive and improper movements that lead to injury. Proprioceptive neuromuscular facilitation (PNF) is a system of balance exercises performed on unstable surfaces (balls, boards). The basic principle on which the exercises are based is the stimulation of maintaining balance in different positions or during different movements. PNF is of great importance in the rehabilitation of patients with injuries of the ligamentous apparatus of the knee joint because it gives good results. The effects of proprioceptive training are: strengthening the kinesthetic feeling of the position and parts of the body in space, increasing the amplitude of movement in the joints, improving balance, strengthening the ligamentous-tendon apparatus [19].

Hydrokinesitherapy - kinesitherapy in water, due to its chemical and physical properties, has certain advantages compared to other exercises. It is important to warn the patients that, although they feel freer in the water and can perform exercises more easily, they must not do inappropriate movements or those that the physiotherapist did not recommend, because this can lead to worsening of symptoms [20]. The specific physical properties of water are the main reason why exercising in water is recommended for patients as a therapeutic procedure, and for healthy people for disease prevention and as training. The force of buoyancy, which acts against the force of gravity, makes it easier to perform upward movements and difficult to perform downward movements, thus acting as resistance. In this way, relief and stabilization of the knees or strengthening of the thigh and other muscles is achieved, depending on the direction of the movement. According to Archimedes' principle "a body immersed in water apparently loses weight equal to the weight of the displaced liquid volume” [21].

Materials and Methods

Sample of Respondents

Retrospective research analyzed the rehabilitation results of 180 male patients with the average age of 28.24±4.36, where the first (initial, -i) isokinetic testing was performed during the period of three to four months (12 - 16 weeks) after the reconstruction of the anterior cruciate ligament of the knee using a hamstring graft. During the sampling, two groups of respondents were formed according to the rehabilitation protocol they implemented.

Tested group A (isokinetic) consisted of patients undergoing rehabilitation at the Institute, 90 male respondents with the average age of 28.54±4.44. Their rehabilitation protocol was based on isokinetic exercises to strengthen the hamstrings muscles, five times a week.

Tested group B (isotonic) consisted of 90 respondents with the average age of 27.93±4.27. They were patients who were undergoing rehabilitation at the Institute with a standard isotonic protocol for hamstrings strengthening. Before the start of the treatment, an initial isokinetic test of the hamstrings was performed at an angular speed of 60º/s. After three and six weeks of rehabilitation treatment, control tests were performed in the same way following the same parameters as in the initial test.

Parameters

The isokinetic parameter used is the torque of the flexor force (Nm) of the operated leg - FLPTRQ.

Study Design

In the examined group A (isokinetic) (90 respondents), the respondents carried out therapy according to the isokinetic exercise protocol, which consisted of one-day isokinetic training for 45 minutes, concentric/concentric contractions of hamstrings at multiple angular velocities. The protocol is designed so that it has a progression by days and weeks (Table 1). Isokinetic training was carried out five times a week for six weeks. For the therapeutic protocol in the tested group B (isotonic exercises), a training room with static bicycles and an EN Dynamic device for strengthening the hamstring muscles, manufactured by Enraf-Nonius BV from Holland, was used. The respondents strengthened the thigh muscles based on standard isotonic exercises to increase muscle strength with additional resistance. The additional resistance was progressively increased every week by 2-5% BM ie. approx. 1 - 5 kg, and on a daily basis during the week, only the number of repetitions could be increased, not the training load. The exercises on the EN Dynamic apparatus lasted about 50-60 minutes in total (Table 1). After the end of the main part of the training, there was a short break of up to 60 seconds, and then stretching exercises were done. The stretch lasted about five minutes.

Table 1. Exercise protocols by group and by week.

Exercise protocols								
	Isokinetic protocol (group A)				Isotonic protocol (group B)			
Weeks	*Number of series*	*Angle velocity*	*Number of repetitions*	*Break (sec.)*	*Number of series*	*Training load (% BM)*	*Number of repetitions*	*Break (sec.)*
I	1	280 °/s	20-25	30	1	3-5	20-25	60
	1	240 °/s	20-22	30	2	8	18-20	60
	1	210 °/s	20-22	30	2	12	15-18	120
	2	180 °/s	18-20	30	3	15	12-15	120
	3	150 °/s	15-18	30	5	20	10-12	120
	3	120 °/s	15-18	30	5	25	8-10	120
	3	90 °/s	15-18	30	6	30	6-8	120
	3	60 °/s	6-8	30	1	3	20-25	120
II	1	280 °/s	25-30	30	1	5	20-25	60
	1	240 °/s	20-25	30	2	10	15-18	60
	1	210 °/s	20-25	30	2	15	12-15	120
	3	180 °/s	15-20	30	3	20	10-12	120
	3	150 °/s	15-18	30	5	25	8-10	120
	4	120 °/s	12-15	30	6	30	6-8	120
	4	90 °/s	15-18	30	7	35	5-8	120
	4	60 °/s	6-8	30	1	3	20-25	120
	1	280 °/s	25-30	30				
III	1	280 °/s	25-30	25	1	5	20-25	30
	1	240 °/s	20-25	25	2	10	15-18	30
	1	210 °/s	20-25	25	3	15	10-12	60
	3	180 °/s	15-20	25	4	20	8-10	60
	3	150 °/s	15-18	25	5	26	8-10	60
	4	120 °/s	12-15	25	7	31	6-8	60
	5	90 °/s	12-15	25	8	36	4-7	60
	5	60 °/s	5-8	25	1	3	20-25	60
	4	45 °/s	3-5	25				
	1	280 °/s	25-30	25				
IV	1	280 °/s	25-30	20	1	5	20-25	30
	1	240 °/s	20-25	20	2	12	15-18	30
	1	210 °/s	20-25	20	3	18	10-12	60
	3	180 °/s	20-25	20	5	22	6-8	60
	4	150 °/s	20-25	20	6	28	6-8	60
	5	120 °/s	18-20	20	8	33	6-8	60
	6	90 °/s	15-18	20	9	38	4-7	60
	6	60 °/s	8-10	20	1	5	20-25	60
	5	45 °/s	5-8	20				
	4	30 °/s	4-6	20				
	1	280 °/s	30	20				
V	1	280 °/s	25-30	20	1	5	20-25	30
	1	240 °/s	20-25	20	2	15	15-18	30
	1	210 °/s	20-25	20	3	20	10-12	30
	3	180 °/s	20-25	20	5	25	5-8	30
	4	150 °/s	20-25	20	7	30	5-8	60

	6 7 7 6 5 1	120 °/s 90 °/s 60 °/s 45 °/s 30 °/s 280 °/s	22-25 15-20 10-12 6-8 5-7 30	20 20 20 20 20 20	8 9 1	35 40 5	5-8 4-7 20-25	60 60 60
VI	1 1 1 3 4 6 7 7 7 6 1	280 °/s 240 °/s 210 °/s 180 °/s 150 °/s 120 °/s 90 °/s 60 °/s 45 °/s 30 °/s 280 °/s	25-30 22-25 22-25 22-25 22-25 22-25 18-22 10-15 8-10 6-8 30	20 20 20 20 20 20 20 20 20 20 20	1 2 3 5 8 9 10 1	5 15 20 25 30 35 40 5	20-25 15-18 10-12 5-8 5-8 5-8 4-7 20-25	30 30 30 30 30 30 60 60

Statistical analysis

Multivariate MANOVA procedures and discriminant analysis were used. Of the univariate procedures, Roy's test was applied. In order to avoid losing information, by finding the finest connections and discoveries, on non-parametric quantities, the data was scaled at contingency tables. This procedure assigns a real number to each class based on frequency. The fact that on scaled values it is possible to apply procedures related to the scale, indicates that in this way new knowledge is obtained in research work, which would not have been achieved by applying procedures and methods related to non-parametric scales. Data scaling does not exclude the application of non-parametric tests. Based on the above, it can be seen that the application of multivariate analysis of variance (MANOVA), discriminative analysis and other parametric procedures and methods is possible on scaled data. Of the univariate procedures, Roy's test, Pearson's contingency coefficient (χ) and multiple correlation coefficient (R) were applied. By calculating the discrimination coefficient, those results of isokinetic testing that determine the specificity of the subsample are separated as well as the results of isokinetic testing that are excluded from further processing, i.e. the reduction of the observed space was performed. We used the Shapiro-Wilk's test to assess the normality of the distribution of individual variables. Considering that according to the mentioned tests in all variables and time moments of measurement (-i, -3, -6) the results of the entire sample do not have a normal distribution at the examined level ($p<.05$), we approached the division of the entire sample into subgroups - classes according to the size of the measured values, from smallest to largest: "smallest", "smaller", "moderate", "larger" and "largest”.

Results

Table 2 presents subgroups (classes), mean values , minimum values (min.), maximum values (max.), and the number of respondents in relation to the class (N), in the total sample at the initial (-i) measurement after three weeks of rehabilitation treatment - transient (-3) and after six weeks of rehabilitation treatment - final (-6) for monitored isokinetic hamstrings parameter.

Table 2. Flexor force torque (Nm) of the operated leg - FLPTRQ at all measurements: (-i), (-3) and (-6) - grouping into classes.

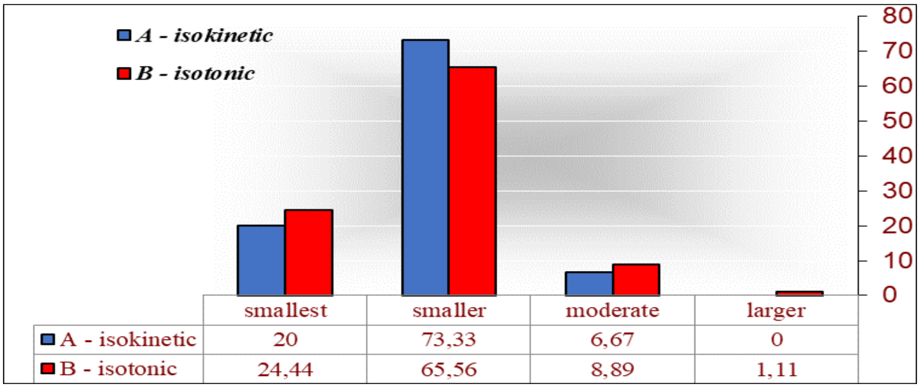
FLPTRQ (Nm) classes:	**mean value**	**min.**	**max.**	**N**
smallest	82.20	64.0	97.1	71
smaller	113.20	97.2	130.2	257
moderate	141.34	130.3	161.8	117
larger	182.55	164.3	196.4	31
largest	209.67	196.7	229.7	64

Initial measurement

Table 3 shows the numerical (n) and percentage (%) representation of monitored isokinetic parameters at the initial measurement in relation to the examined groups. With the descriptive procedure, it is only possible to hint at some characteristics of certain levels of isokinetic parameters, while the significance of the difference between the examined groups was analyzed later.

Table 3. Numerical (n) and percentage (%) representation of classes - modality of isokinetic parameter, torque of flexor force (Nm) of the operated leg - FLPTRQ (-i) at the initial measurement in relation to the examined group.

Classes - modalities	**smallest**		**smaller**		**moderate**		**larger**	
Examined groups	n	%	n	%	n	%	n	%
A - isokinetic	18	20.0	66	73.3	6	6.7	0	.0
B - isotonic	22	24.4	59	65.6	8	8.9	1	1.1



Graph 1. FLPTRQ classes (-i) according to the examined groups on the initial measurement.

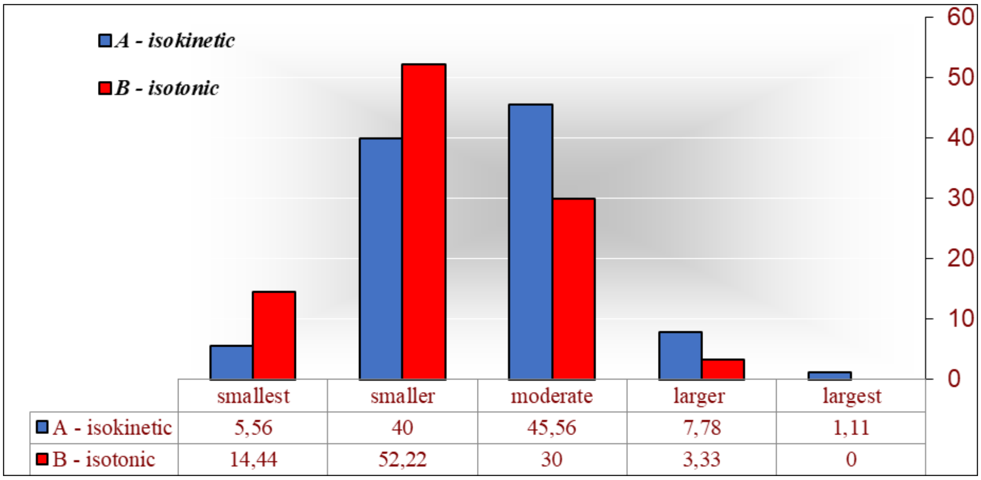
Table 3 shows that it is possible to notice that in the examined group **A - isokinetic**, the **"smaller"** class is the most represented, comprising 66 respondents (73.3%) out of a total of 90, and it is significantly higher than the frequency of the **"smallest"** class (18 respondents, 20.0%, p=.000), followed by the **"moderate"** class (6 respondents, 6.7%, p=.000), then the **"larger"** class (0 respondents, .0%, p=.000). In the examined group **B - isotonic**, the representation of the **"smaller"** class (59 respondents, 65.6%) is significantly higher than the **"smallest"** class (22 respondents, 24.4%, p=.000), followed by the **"moderate"** class (8 respondents, 8.9%, p=.000), and the **"larger"** class (1 respondent, 1.1%, p=.000).
The difference between the examined groups is **insignificant**. The ***"smallest"*** class is most represented in the examined group **B - isotonic** (24.44%), the ***"smaller"*** class is most represented in **group A - isokinetic** (73.33%), the ***"moderate"*** class is most represented in group **B - isotonic** (8.89%), and the ***"larger"*** class is the most represented in the tested group **B - isotonic** (1.11%).
Based on the obtained results, it is possible to examine the eventual characteristics of each examined group in relation to each flexor isokinetic parameter at the initial measurement separately. Thus, we see that for the isokinetic parameter, the torque of the flexor force (Nm) of the operated leg - FLPTRQ (-i), it implies that in the examined group **A - isokinetic**, the characteristics of the ***"smaller"*** class are very weakly expressed, while in the examined group **B - isotonic**, the characteristics are not defined at all. Thus, we can see that the difference between the examined groups is **insignificant**. As p = 0.556 of $\chi 2$ test, it can be said that **there is no correlation** between the examined groups and the torque of the flexor force (Nm) of the operated leg - FLPTRQ (-i), considering that χ= 0.107 the correlation is **very low**.

Transient measurement after three weeks

Table 4. shows the numerical (n) and percentage (%) representation of the analyzed parameter. Attention was drawn to significant differences between and within the levels of the examined groups. Descriptive procedure indicates the characteristics of certain parameter levels, while the significance of the differences between the examined groups was later analyzed.

Table 4. Numerical (n) and percentage (%) representation of classes - modalities of the torque of the flexor force (Nm) of the operated leg - FLPTRQ (-3) on the transient measurement in relation to the examined groups.

Classes-modalities	**smallest**		**smaller**		**moderate**		**larger**		**largest**	
Examined groups	n	%	n	%	n	%	n	%	n	%
A - isokinetic	5	5.6	36	40.0	41	45.6	7	7.8	1	1.1
B - isotonic	13	14.4	47	52.2	27	30.0	3	3.3	0	.0



Graph 2. Classes of FLPTRQ (-3) according to the examined groups on the transient measurement.

Table 3. indicates that it is possible to notice that in the examined group A - isokinetic, the "moderate" class is the most represented, consisting of 41 respondents (45.6%) out of a total of 90, and it is significantly higher than the frequency of the ***"larger"*** class (7 respondents, 7.8%) , p=.000), then the ***"smallest"*** class (5 respondents, 5.6%, p=.000) and the ***"largest"*** class (1 respondent, 1.1%, p=.000). In the examined group **B - isotonic**, the representation of the ***"smaller"*** class (47 respondents, 52.2%) is significantly higher than the frequency of the ***"moderate"*** class (27 respondents, 30.0%, p=.003), then the ***"smallest"*** class (13 respondents, 14.4%, p=.000), then the ***"larger"*** class (3 respondents, 3.3%, p=.000), and the ***"largest"*** class (0 respondents, .0%, p=.000).

The difference between the examined groups: the ***"smallest"*** class is most represented in the examined group **B - isotonic** (14.44%), which is significantly more than the representation in the examined group **A - isokinetic** (5.56%, p=.048), and the ***"smaller"*** class is most represented in the examined group **B - isotonic** (52.22%), and the ***"moderate"*** class is most represented in the examined group **A - isokinetic** (45.56%), which is significantly more than the representation in the examined group **B - isotonic** (30.00% p =.033), and the ***"larger"*** class is the most represented in the examined group **A - isokinetic** (7.78%), and the ***"largest"*** class is the most represented in the examined group **A - isokinetic** (1.11%).

Based on the obtained results, it is possible to distinguish the characteristics of each examined group in relation to the isokinetic parameter torque of the flexor force (Nm) of the operated leg - FLPTRQ (-3), so it implies that the examined group **A - isokinetic** has a more pronounced property of the ***"moderate"**** class, while the examined group **B - isotonic** has a more pronounced property of the ***"smallest"**** class.

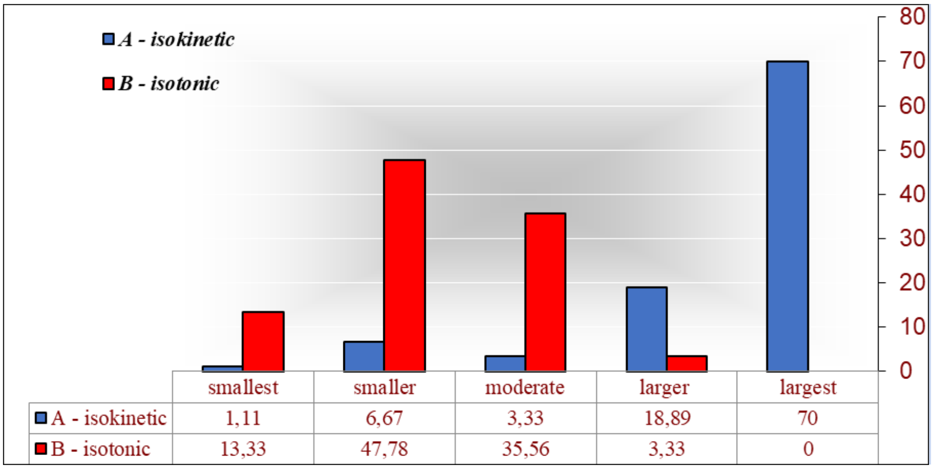
Since p = 0.033 of the $\chi 2$ - test, it can be said that **there is a correlation between the examined groups** and the isokinetic parameter torque of the flexor force (Nm) of the operated leg - FLPTRQ (-3), and considering that χ= 0.235, **the connection is low.**

Final measurement after six weeks

Table 5. shows the numerical (n) and percentage (%) representation of isokinetic parameter torque of the flexor force (Nm) of the operated leg - FLPTRQ (-6) at the final measurement. We drew attention to significant differences between and within the levels, that is, the examined groups. With the descriptive procedure, it is only possible to hint at some characteristics of certain levels of flexor isokinetic parameters, while the significance of the difference between the examined groups was analyzed later.

Table 5. Numerical (n) and percentage (%) representation of classes - modalities of the isokinetic parameter torque of the flexor force (Nm) of the operated leg - FLPTRQ (-6) at the final measurement in relation to the examined groups.

Classes - modalities	**smallest**		**smaller**		**moderate**		**larger**		**largest**	
Examined group	n	%	n	%	n	%	n	%	n	%
A - isokinetic	1	1.1	6	6.7	3	3.3	17	18.9*	63	**70.0***
B - isotonic	12	13.3	43	47.8*	32	35.6*	3	3.3	0	.0



Graph 3. Classes of FLPTRQ (-6) according to the examined groups on the final measurement.

Table 5. shows that it is possible to notice that in the examined group **A - isokinetic**, the ***"largest"*** class is the most represented, which makes up 63 respondents (70.0%) out of a total of 90, which is significantly higher than the frequency of the ***"larger"*** class (17 respondents, 18.9%, p=.000), followed by the ***"smaller"*** class (6 respondents, 6.7%, p=.000), then the ***"moderate"*** class (3 respondents, 3.3%, p=.000), then the ***"smallest"*** class (1 respondent , 1.1%, p=.000).

In the examined group **B - isotonic**, the representation of the ***"smaller"*** class (43 respondents, 47.8%) is significantly higher than the frequency of the ***"moderate"*** class (32 respondents, 35.6%, p=.098), followed by the ***"smallest"*** class (12 respondents , 13.3%, p=.000), the ***"larger"*** class (3 respondents, 3.3%, p=.000) and the ***"largest"*** class (0 respondents, .0%, p=.000).

The difference between the examined groups: the ***"smallest"*** class is most represented in the examined group **B - isotonic** (13.33%), which is significantly more than the representation in the examined group **A - isokinetic** (1.11%, p=.002), and the ***"smaller"*** class is the most represented in the examined group **B - isotonic** (47.78%), which is significantly more than the representation in the examined group **A - isokinetic** (6.67%, p=.000), then the ***"moderate"*** class is the most represented in the examined group **B - isotonic** (35.56%), which is significantly higher than the representation in the examined group **A - isokinetic** (3.33%, p=.000), the ***"larger"*** class is the most represented in the examined group **A - isokinetic** (18.89%), and that is significantly more than the representation in the examined group **B - isotonic** (3.33%, p=.001), and the ***"largest"*** class is the most represented in the examined group **A - isokinetic** (70.00%), which is significantly more than the representation in the examined group **B - isotonic** (.00% p=.000).

On the basis of the obtained results, it is possible to separate the characteristics of each examined group in relation to the isokinetic parameter, the torque of the flexor force (Nm) of the operated leg - FLPTRQ (-6), so it implies that the examined group **A - isokinetic** has **the most pronounced characteristics** of the class ***"larger"**** and "***largest***"*, while the examined group **B - isotonic** has **the most pronounced characteristics** of the "smallest"* and "smaller"* classes. Since p = .000 of the $\chi 2$ test it can be said that there is a correlation between the examined groups and the isokinetic parameter torque of the flexor force (Nm) of the operated leg - FLPTRQ (-6) at the final measurement, and given that χ= .653 **the correlation is high**.

Discussion

At the **initial measurement** $\chi 2$ - test (p = 0.556) shows that **there is no correlation** between the examined groups and the torque of the flexor force (Nm) of the operated leg - FLPTRQ (-i), and considering that χ = 0.107 the correlation is **very low**. Flexor torque values (Nm) of the operated leg - FLPTRQ(-i) were low and moderately low at the initial measurement. As we can see, at the initial measurement it was quite uniform regarding the classes of this parameter. At the **control measurement**, the most represented class in the examined group **A - isokinetic** is "*"moderate"* with 41 (45.56%) respondents, then the *"smaller"* class with 36 (40.00 %) respondents, followed by the *"larger"* class with 7 (7.78%) respondents, the *"smallest"* class with 5 (5.56%) respondents and the "*largest"* class with only one (1.11%) respondent. In the examined group **B - isotonic**, the most represented class was *"smaller"* with 47 (52.22%) respondents, then the "*moderate"* class with 27 (30.00%) respondents, then the *"smallest"* class with 13 (14.44%) respondents, and the class " *larger"* with 3 (3.33%) respondents, while there were no respondents in the "*largest"* class (0.00%). At this level (three weeks), there was obviously a difference in the examined groups, although it was not so significant. What is significant is that there was an improvement in the results of the isokinetic parameter torque of the flexor force (Nm) of the operated leg - FLPTRQ (-3) in both examined groups, i.e. that there is a visible increase in the torque of hamstring.

At the **final measurement**, the most represented class in the examined group **B - isotonic** was "*smaller"* with 43 (47.78%) respondents, followed by class *"moderate*" with 32 (35.56%) respondents, and "*smallest"* with 12 (13.33%) respondents. There were only 3 (3.33%) respondents in the *"larger"* class, while there were no respondents in the "*largest"* class (0.00%). A slight increase in the isokinetic parameter, the torque of the flexor force (Nm) of the operated leg - FLPTRQ (-6) at the final measurement in the examined group B - isotonic, but not to such an extent compared to the examined group A. The most represented class in the examined group **A - isokinetic** was ***"largest**** " with 63 (70.00%) respondents, then ***"larger"*** with 17 (18.89%) respondents, followed by the *"smaller"* class with 6 (6.67%) and the *"moderate*" class with 3 (3.33%) respondents and the "*smallest"* class with only one (1.11%) respondent.

After ACL reconstruction, a frequent occurrence is the weakening of the muscles of the hamstring precisely because of the choice of graft itself. Successful ligament reconstruction with a tendon graft requires firm and rapid healing of the transplanted tendons in the bone tunnels [22]. There is a lot of data in the literature comparing the results of ACL reconstruction using different grafts, however, there is still no consensus regarding the superiority of one graft over another [23, 24]. Several systematic review reports and meta-analyses [25, 26–28, 29, 30, 31] have compared multiple graft choices, with results showing no difference in rehabilitation outcomes between these autografts. Our research showed that patients from the examined group A - isokinetic, who were rehabilitated using the isokinetic rehabilitation protocol, had significantly better knee flexor torque values at an angular speed of 60°/s after three and six weeks of rehabilitation than patients who were rehabilitated with the classic rehabilitation protocol. A group of researchers found that by applying a hamstring graft for ACL reconstruction, the strength of the hamstring was weakened by as much as 17% [32], and our research also found much greater weakening, even over 30%, and many other studies also prove the same [33, 34]. We found no studies that disprove the results of this research. Since the hamstring muscles are agonists of the ACL, the recovery of hamstring muscle strength is important after ACL reconstruction, and it can be said that this is of particular importance for the hamstring muscles [35]. Morphological studies with cross-sectional analyses of the affected thigh muscles with the help of computed tomography have shown that the atrophy of the muscle tissue of the hamstring is very pronounced after an ACL injury [36, 37]. Studies of thigh muscle strength have also shown that muscle strength deficits were extremely large [38, 39]. In our research, in patients after reconstruction of the anterior cruciate ligament, who performed an isokinetic therapeutic exercise protocol, a significant improvement in knee flexor torque was found after six weeks of rehabilitation treatment. One of the possible reasons is that with isokinetic exercise, the strength of the hamstring is achieved more quickly and efficiently with a minimum of side effects, such as pain and fatigue.

Other authors also confirm the dominance of isokinetic exercise in the restoration of the torque of the hamstring after knee surgery [40, 41, 42].

Conclusion

Analysis of the results of the monitored isokinetic parameter at the initial measurement (MANOVA .000 and DISCRIMINATIVE .000) indicates that there is no difference between the examined groups and this parameter, with the discrimination coefficient for the torque of the flexor force (Nm) of the operated leg– FLPTRQ (.027). The analysis of the results of the control measurement (MANOVA .000 and DISCRIMINATIVE .000) indicates that there is a significant difference between the two examined groups, so that the torque of the flexor force (Nm) of the operated leg – FLPTRQ (-3) (.001). The discrimination coefficient for the isokinetic parameter flexor force torque (Nm) of the operated leg - FLPTRQ (-3) is (.000). Analysis of the results of the monitored isokinetic parameter at the final measurement (MANOVA .000 and DISCRIMINATIVE .000) indicates that there is a significant difference between the examined groups regarding the torque of the flexor force (Nm)of the operated legs - FLPTRQ (-6) (.000).

The general conclusion of this research is that an isokinetic approach to kinesitherapy with the purpose of restoring the torque of the hamstring muscles after surgical reconstruction of the anterior cruciate ligament of the knee is more dominant than the standard - isotonic approach. It seems that isokinetic training is a better solution than classical training for the repair of muscle performance of the hamstring (knee flexors), twice as much.

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IZOKINETIKA U KINEZITERAPIJI NAKON REKONSTRUKCIJE PREDNJEG UKRŠTENOG LIGAMENTA

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Sažetak. *Jedna od najčešćih povreda u sportu i rekreaciji je povreda prednjeg ukrštenog ligamenta koljena, a kao posljedica ove povrede može u velikom broju slučajeva da se javi slabost mišića natkoljenice i trajno onesposobljenje koljena. Iako je ova tema obilato istraživana, još uvijek ne postoje ujednačeni standardi rehabilitacije ovih pacijenata. Cilj ovoga rada je da prikaže i objasni neke od koristi izokinetičkog treninga u rehabilitaciji oslabljenih mišića kod pacijenata nakon rekonstrukcije prednjeg ukrštenog ligamenta. Retrospektivnim istraživanjem praćeno je 180 pacijenata muškog pola, tri mjeseca nakon rekonstrukcije prednjeg ukrštenog ligamenta koljena. Pacijenti su podijeljeni u dvije ispitivane grupe prema vrsti rehabilitacionog protokola koji su provodili. U grupi A-izokinetičkoj ispitanici su u kineziterapiji provodili izokinetičko vježbanje. Ispitanici grupe B-izotoničke su provodili kineziterapiju baziranu na standardnim vježbama u okviru rehabilitacionog tretmana, ali sa izotoničkim vježbama. Protokoli su koncipirani tako da imaju progresiju po danima i sedmicama. Efekat rehabilitacije objektivizovan je izokinetičkim testom mišića fleksora koljena pri ugaonoj brzini od 60°/s prije tretmana, nakon tri sedmice i nakon šest sedmica tretmana. Ispitivani parametar je bio obrtni moment fleksora operisane noge – FLPTRQ (Nm). Period praćenja je bio šest sedmica. Nađene su statistički značajne razlike ($p<0,05$) u praćenom parametru u obje ispitivane grupe, ali u grupi A-izokinetičkoj je bio značajno veći nakon šest sedmica tretmana u odnosu na grupu B-izotoničku. Rezultat primjene izokinetičkog vježbanja je znatno bolji u odnosu na kineziterapijski rezultat vježbanja standardnim izotoničkim protokolom. Na osnovu navedenog izvodi se zaključak da je izokinetički protokol efikasniji metod u restauraciji obrtnog momenta zadnje lože natkoljenice kod pacijenata nakon rekonstrukcije prednjeg ukrštenog ligamenta u odnosu na standardni protokol.*

Ključne riječi*: izokinetika, prednji ukršteni ligament, fizioterapija, rehabilitacija*