

CHANGES IN STATIC FORCE STRENGTH OF M. QUADRICEPS FEMORIS IN PATIENTS WITH "O'DONOGHUE'S TRIAD"

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Abstract: One of the most serious sports injuries, injuries in accidents and severe work accidents is the O'Donoghue Triad, which is a multiligamentous injury to the knee joint. Includes rupture of the anterior cruciate ligament, meniscus, and medial collateral ligament. It is also called the "Unfortunate Triad", "Unhappy Triad" due to the fact that a large percentage of athletes with this injury do not return to the sport. Recovery after surgical treatment is about one year. Static instability in the knee joint recovers immediately after surgery, but dynamic instability persists for months after ligament reconstruction. One of the causes of dynamic instability of the knee complex is the suppressed strength capabilities of the periarticular muscles, one of which is *m. quadriceps femoris*. Purpose: The purpose of this study is to establish the effectiveness of an experimental model of kinesitherapy for recovery the static strength endurance of *m. quadriceps femoris*, after arthroscopic treatment of O'Donoghue's triad. Methodology: 70 patients with "O'Donoghue's triad" were studied after surgical treatment in the subacute postoperative period, of which 32 were included in the control group (CG) and 38 in the experimental group (EG). To assess the condition and recovery of static muscle endurance of *m. quadriceps femoris* was tested twice, before and after ten days of kinesitherapy in CG and EG. Test of the static muscular endurance of the *m. quadriceps femoris*: the patient is in the starting position supine, the tested leg is extended at the knee joint and raised 30 cm from the support. The retention time (until failure) in the set position (in sec.) is counted. In the measurements, a normative limit of up to 4 minutes of isometric loading (240 sec) was adopted. The differences in the data of the healthy and damaged limb (in sec) were subjected to statistical processing and analysis. An experimental model of kinesitherapy applied in EG was developed, and a traditional model was applied in CG. Results: The results of the study show that on the 1st day, the average difference in strength endurance of healthy-injured leg of CG patients is 101.375+48.938 sec. The representative error is $m_x=12.2$ sec. Variability of results $V\%=48.27\%$. After ten days of kinesitherapy, the difference in static strength endurance decreased to 67.5 seconds. or in absolute values the decrease is by 33.875 sec., and in relative values the difference has decreased by 33.416%. The results in the EG show a high mean difference in the static power endurance of the leg of 104.947+50.378 sec. on the first day of the study. The representative error is $m_x=11.558$ sec. The variability of the results in the EG on the 1st day is $V\%=48.0\%$. After applied experimental kinesitherapy in EG, the static strength endurance of the injured leg drastically improved and the difference with the healthy leg decreased by 79.689% or in absolute values by 83.632 sec (in CG by 33.416%). The mean values of the healthy-injured leg difference on the X-th day decreased to 21.316 sec. Conclusions: From the testing of hypotheses, it is established that on the first day of the study, the difference in the average values of the indicator in CG and EG are statistically insignificant ($P=1.000$). At the end of the study on the tenth day, the difference found was significant ($P=0.002$) and the better results in the EG indicated a higher effectiveness of the experimental model of kinesitherapy to improve the static strength endurance of the *m. quadriceps femoris*, after surgical treatment of "O'Donoghue's Triad", compared to the traditional model of kinesitherapy, which is why we recommend it for practice.

Keywords: physiotherapy, unhappy triad, terrible triad, knee, kinesitherapy, sports injuries

1. INTRODUCTION

The "O'Donoghue triad" is considered a severe multiligamentous primarily sports knee injury and includes an anterior cruciate ligament (ACL) tear, medial meniscus tear, and medial collateral ligament (MCL) tear.

It is also called the "Unhappy triad", "Unfortunate triad", "Terrible triad" because a large percentage of athletes do not return to the sport (Gramatikova et al., 2022; Avramova et al., 2023). When O'Donoghue first described this triad, he suspected it occurred due to lateral blocking or the cut-back motion (footin external rotation with stress over the MCL) (O'Donoghue, 1950). Later, case series reported the most frequent etiologies being sports-related injuries (Daher et al., 2022).

Treatment of O'Donoghue's triad is surgical. The capsuloligamentary structures (the passive, static stabilizers of the knee joint) are restored immediately after surgery, but dynamic instability of the knee persists for months after ligament reconstruction. Dynamic joint stability is provided by the adjacent muscles of the knee complex.

One of the most powerful dynamic knee stabilizers is *m. quadriceps femoris*, but its strength abilities are suppressed due to pain, edema, reflex muscle inhibition, impaired proprioception and muscle control (Grueva-Pancheva et al., 2021), hypodynamia, muscle imbalance, impaired gait and other factors.

Kinesitherapy aims to restore arthrokinematics and dynamic joint stability, fully restore the functional abilities of patients and return them to the rhythm of their normal activities - complex motor activities from daily life, hobbies, work, including athletes to their high sportsmanship (Gramatikova, 2021).

To restore the motor function and dynamic stability of the knee joint, kinesitherapy programs include means for improving the dynamic and static strength endurance (Valchev et al., 2022) of the periarticular muscles.

Means are applied to restore their mass and strength abilities, reduced by hypodynamia, suppressed by reflex muscle inhibition and impaired muscle control (proprioception) (Gramatikova et al., 2016).

The motor function is impaired, and its recovery is of utmost importance for patients and kinesitherapists, which directed our attention to the study of the possibilities of a kinesitherapy program to restore the strength capabilities of the main knee extensor *m. quadriceps femoris* in patients, after surgical treatment of "O'Donoghue's Triad".

2. MATERIALS AND METHODS

Purpose: Establishing the effectiveness of an experimental model of kinesitherapy to restore trauma-suppressed static strength endurance of the *m. quadriceps femoris*, after arthroscopic treatment of O'Donoghue's triad.

Research methodology: To achieve the goal, the following tasks are set:

- Development of an experimental model of kinesitherapy to improve the static strength endurance of *m. quadriceps femoris*.
- Study of the initial state of the static strength endurance of *m. quadriceps femoris*, before kinesitherapy.
- Carrying out a ten-day kinesitherapy according to the traditional model in the control group and an experimental model in the experimental group of patients.
- Establishing the end state of the static strength endurance of *m. quadriceps femoris*, after the course of kinesitherapy.
- Statistical processing of the empirical material, analysis and evaluation of the effectiveness of the experimental model of kinesitherapy.

Organization of the study: The study was conducted in the period from 2013 to 2020, in Sofia at the General hospital for active treatment "Saint Sofia", Military Medical Academy, Government Hospital and in a kinesitherapy office in the city of Bansko. The present study is part of a larger study of the effectiveness of an experimental model of kinesitherapy on a large number of indicators, one of which is its effect on the static strength endurance of the *m. quadriceps femoris*, after surgical treatment of "O'Donoghue's Triad".

Study contingent: 70 patients were studied, distributed as follows: 32 were included in the control group (CG) and 38 in the experimental group (EG). All have "O'Donoghue's triad": total anterior cruciate ligament rupture reconstructed with lig autograft. patellae, by the BPTB (Bone-Patellar Tendon-Bone) method; with rupture of the medial meniscus treated with partial meniscectomy; and the damage to the medial collateral ligament was treated conservatively, and the knee was immobilized 1 month before the operation. Patients are in a subacute postoperative period. In the study, we did not include patients with a meniscus suture and with surgical repair of the MCL.

The study was preceded by individual informed consent of the patients.

Functional examination: To assess the condition and recovery of static muscular endurance of *m. quadriceps femoris* was tested twice, before and after ten days of kinesitherapy in CG and EG. **Test:** the patient is in the starting position supine, the tested leg is extended at the knee joint and raised 30 cm from the support. The retention time (until failure) in the set position (in sec.) is counted.

The measurement is an acceptable normative limit of up to 4 minutes of isometric loading (240 sec) (Gramatikova, 2021). The test is performed twice for the injured lower limb, on the first day - before kinesitherapy and on the tenth day after the kinesitherapy course. The healthy leg is tested once, on the 1st day, before kinesitherapy. The differences in the values of the healthy and damaged limb (in sec) are proposed for analysis.

The kinesitherapy program at CG follows established standards and a traditional model is applied. An experimental model has been developed for EG and includes: Instrumentally Assisted Soft Tissue Mobilization - **Ergon IASTM technique**, for restoring myo-articular laxity, for pain suppressive effect, for reducing edema of the knee joint (Zlatkova et al., 2022) and for elasticity of the cicatrix; **kinesio tape** for pain-suppressant and drainage effect, for joint stabilization, cicatrix correction; **Post isometric relaxation and stretching**, to restore the range of motion in the knee joint; **analytical specialized strength training** of the operated limb; **proprioceptive training** (complexes of exercises for balance on an unstable support, balance, for proprioceptive sensitivity, neuromuscular control, to improve dynamic joint stability); **locomotor training on a treadmill**, to restore the motor stereotype

when walking, normalize the load on the injured limb, normalize the locomotor abilities of patients and neutralize adaptive pathological changes in walking.

The statistical processing of the empirical material was carried out with the SPSS program to evaluate the effectiveness of the experimental model of kinesitherapy, to restore the static strength endurance of m. quadriceps femoris, after arthroscopic treatment of O'Donoghue's triad.

3. RESULTS

The results of the study show that on the 1st day, the average difference in strength endurance of healthy-injured lower limb of patients from the control group is 101.375 ± 48.938 sec. (Fig.1). The representative error $m_x = 12.2$ sec., which defines a confidence interval of the general population of patients at $\Delta = x \pm m_x$ from 52.437 to 150.313 sec. The coefficient of variation is high $V\% = 48.27\%$, which indicates a high heterogeneity of results in the group (Table 1.).

After ten days of kinesitherapy, the difference in static strength endurance of a healthy-injured lower limb in CG decreased to 67.5 seconds or in absolute terms the decrease is 33.875 sec. and in relative terms the difference has decreased by 33.416%. Therefore, the indicated result shows a good effectiveness of applications in the control group of a traditional model of kinesitherapy.

Table 1. Changes in the static strength endurance of m. quadriceps femoris, after kinesitherapy (healthy-injured leg difference in sec.)

Signs	Control group				Experimental group			
	On the 1st day	On the 10th day	D	D%	On the 1st day	On the 10th day	D	D%
\bar{X}	101,375	67,500	33,875	33,416	104,947	21,316	83,632	79,689
SD	48,938	50,173			50,378	29,637		
m_x	12,234	12,543			11,558	6,799		
$V\%$	48,274	74,330			48,003	139,037		
A	0,291	0,529			0,336	1,535		
E	0,095	-0,637			-0,659	1,495		

And the results in the experimental group showed a high mean difference in the static strength endurance of the lower limbs of 104.947 ± 50.378 sec. on the first day of the study, which speaks of a severe condition of the injured knee joint and the impossibility of showing significant strength endurance of the injured limb.

The representative error is with values close to those found in the control group or $m_x = 11.558$ sec. And the variability of the results in the experimental group on the 1st day is similar to that found in the control group or $V\% = 48.0\%$ (in CG 48.274%) (Table 1.). The skewness and kurtosis coefficients are within (-1.1) on the first day of the study. After applied experimental kinesitherapy in EG, the static strength endurance of the injured lower limb drastically improved and the difference with the healthy leg decreased by 79.689% or in absolute values by 83.632 sec. (in CG by 33.416%).

The mean values of the healthy-injured leg difference on the X-th day decreased to 21.316 sec. (in CG the difference is 67.5 sec. on the 10th day) (Fig.1). It also decreases SD in the experimental group as from 50.378s. on the 1st day it decreases to 29.637 sec.

The statistical error of 11.558 seconds has also been reduced. at 6.799 sec. at the end of the study, which favorably affects the confidence interval of \bar{x} of the general population of patients with "Donoghue's triad".

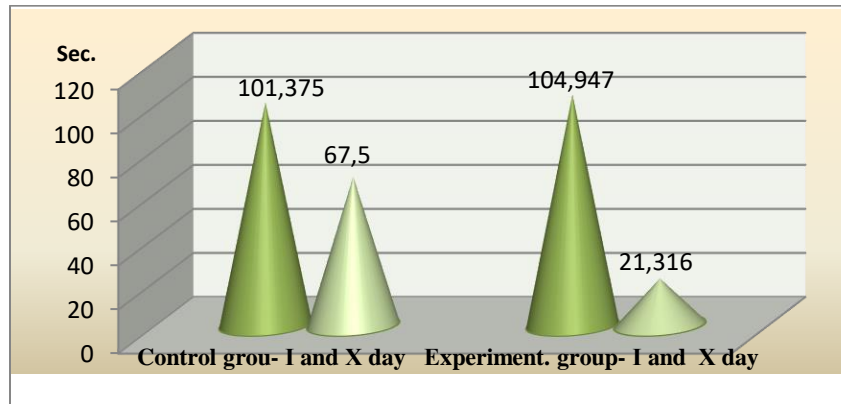


Fig.1 Difference in static strength endurance of *m. quadriceps femoris* of a healthy-injured lower limb, before and after kinesitherapy

It was found, however, a significant increase in the variability of the results in the experimental group from the 1st to the 10th day, as V% from 48 sec. reaches up to 139 sec. This is an indication of a marked individual intensity of restoring the static power endurance of the injured limb of the patients in the group, which requires a strict individual approach to the dosage of physical effects in restoring the specified motor ability of the injured leg of the patients.

Or the results show a significantly higher effectiveness of the applied experimental model of kinesitherapy in the experimental group, to improve the static strength endurance of *m. quadriceps femoris*, of the injured lower limb compared to the traditional model applied in the control group of patients.

To determine the criterion for hypothesis testing, the normality of the distribution of the results was investigated, with set limits of A and E of (-1,1).

Table 2. Mann-Whitney p-values

Variable	CG- X1	S1	EG-X2	S2	D =X2-X1		D%
					P value	In absolute values	
On the 1st day	101,375	48,938	104,947	50,378	1,000	3,572	3,524
On the 10th day	67,500	50,173	21,316	29,637	0,002	46,184	68,421

From the results presented in the (Table 1.), it is clear that A and E in the experimental group are outside the specified limits, which determines a non-normal distribution of cases, therefore the non-parametric Mann-Whitney criterion was applied.

From the testing of hypotheses, it is clear that on the first day of the study (Table 2.), the difference in the average values of the indicator in CG and EG are statistically insignificant (P=1.000).

However, at the end of the study on the tenth day, the difference found was significant (P=0.002) (Table 2.) and the better results in the experimental group indicated a higher effectiveness of the experimental model of kinesitherapy to improve the static strength endurance of the *m. quadriceps femoris* of the damaged lower limb of patients with "Donoghue's Triad" of the knee joint, compared to the classic model applied in the control group.

4. DISCUSSIONS

- ✓ The initial and final state of the static strength endurance of the quadriceps femoris, before and after ten days of kinesitherapy, were studied. A ten-day kinesitherapy was carried out according to the traditional model in the control group and an experimental model in the experimental group of patients.
- ✓ An experimental methodology of kinesitherapy was developed and approved to improve the static strength endurance of *m. quadriceps femoris*, after surgical treatment of "Donoghue's Triad".

- ✓ After statistical processing of the empirical material, the result shows a good effectiveness of applications in the control group of a traditional model of kinesitherapy to improve the static strength endurance of *m. quadriceps femoris*.
- ✓ The coefficient of variation in the experimental group on the 1st day is similar to that found in the control group or $V\% = 48.0\%$ (in CG 48.274%), which speaks of high heterogeneity of the results in both groups.
- ✓ From the testing of hypotheses, it is evident that on the first day of the study, the difference in the mean values of the indicator in CG and EG are statistically insignificant ($P=1,000$). However, at the end of the study on the tenth day, the difference found was significant ($P=0.002$) and the better results in the experimental group indicated a higher effectiveness of the experimental model of kinesitherapy to improve the static strength endurance of the *m. quadriceps femoris* of the damaged lower limb of patients with "Donoghue's Triad" compared to the classical model applied in the control group.

5. CONCLUSIONS

The reliability of the scientific claims has been proven, through the methods of mathematical statistics, verified reliability of the test battery and a large contingent of examined patients.

The results of the conducted research show that the experimental model of kinesitherapy applied in EG is more effective in restoring the suppressed strength abilities of *m. quadriceps femoris* in patients after surgical treatment of "O'Donoghue's Triad", compared to applications in CG traditional model of kinesitherapy, therefore we recommend it for the practice.

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