KINESITHERAPY RECOVERY OF THE STRENGTH ENDURANCE OF M.QUADRICEPS FEMORIS AFTER RECONSTRUCTION OF THE ACL

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Abstract
A research on the effectiveness of two kinesitherapy programs- traditional and experimental has been conducted. The period to start the recovery of isometric strength endurance of m.quadriceps femoris after reconstruction of the anterior cruciate ligament has been established. The recovery in the second post-operation month is related to reducing the negative factors to display available, but hampered strength endurance, due to pain, swelling, muscle reciprocal, muscle inhibition and other factors. The testing is before and after a ten day kinesitherapy. A difference in seconds in strength endurance of m.quadriceps of the healthy and the damaged leg on the first day in the control group by 96.19 ± 10.36 sechas been established through the test „of occipital leg - lifting to 30 cm the extended operated leg and holding it“.After the kinesitherapy the results are improved by 37, 6% and the difference between the two legs is reduced to 60, 03±8, 81 seconds. In the experimental group the difference in the power endurance of m.quadriceps of the two legs is 91, 16±9, 07 at the first examination while after the kinesitherapy it is 16, 25±4,28 seconds. The recovery is by 82.17% (74.91 sec.). In the first study P = 0.559 and in the final P = 0,000, indicating a high efficiency of the experimental model of physiotherapy and its ability to create conditions for an early start for the recovery of strength endurance of the operated leg and its subsequent development.

Key words: kinesitherapy, knee joint, ACL, rehabilitation, isometric strength endurance

Introduction
The main aim of the soft tissue damage treatment is reconstruction and strengthening of the adjacent capsule of the knee ligament structures to restore its function, and implement the kinesitherapeutic programs, which together passively or after stabilizing elements, improve dynamic and static power and strength endurance of the periarticular muscles. Or means for restoring the muscle mass and strength, decreased by immobilization leading to muscle atrophy applied. The soft tissue knee damage and the efficiency of the kinesitherapeutic programs have been a subject of scientific research of authors such as R. Kostov, (2013), who develops and approbates different techniques for manual mobilizations of the knee joint after soft tissue damage. M. Gramatikova, (2015) develop and approbate a program for aqua therapy and kinesitherapy for recovering of the static and dynamic myo-articular stability, for recovering of the explosive power (M.Gramatikova, E.Nikolova, St.Mitova (2014). W.Mesfar, A.Shirazi-Adl, (2008) and investigate the biomechanics of the knee joint and the effect on myo-articular structures including that of the anterior crucial ligament (after reconstruction) while executing exercise for knee extension in an open kinematic chain (E.Ageberg et al.(2009), M.Perry et al. (2005), M.Uçar et al. (2014). An important matter for motor function of patients is to recover the ability of the muscles to manifest strength endurance. Power endurance and more particularly the static power endurance presents the maximum magnitude of the force shown by a muscle or a muscle group for long periods (or until refusal to work) at the maximum tension. The isometric extortion of the damaged leg of the patients is related to balancing the manifested internal and external forces that generated power without changing the linear dimensions of the muscle or the muscle group. The occurrence of muscle strength is a result of the body's ability to convert chemical potential energy in the tissues - in physical work in the form of engine performance or keeping the position of the body and its parts. Meanwhile in a biochemical way a system of levers on the damaged limb, articulated by joints, transmits and applies energy produced as muscle traction. At the occurrence of static power endurance of the patient’s damaged leg a priority is given to slow oxidative muscle fibers of type I, characterized by low myosin ATP activity and decreased ability to anaerobic digestion. At the same time there is high intensity respiratory phosphorylation, presence of many mitochondria, myoglobin and enriched capillary network, which is a precondition for a productive, prolonged, slow or static physical work of the muscles. According to K.Simeonov, (2008), the physical exercise is a process in which the "under the influence of external factors are made positive functional and structural changes in the different systems of the organism". The peculiarities of impact of power exercises in different physiological modes, including power endurance have been investigated by a number of authors, and are
established peculiarities in adaptation changes of the muscles and the body, as a result of loads on power endurance V.Boyanov,(1996), V.Boyanov,(1998). In case of soft tissue damage of the knee, due to immobilization and the atrophy of adjacent muscles, the activity of these processes is reduced. Their motor function is deteriorated, the restoration of which is of highest importance for the kinesitherapeutist. This drew our attention to explore the possibilities of a program of kinesitherapy to recover the static strength endurance of the main extensor of the knee m.quadriceps femoris in patients after reconstruction of the anterior cruciate ligament, the results of which will be set out below.

Methods

Study Hypothesis
We assume that developing and applying of a contemporary (experimental) model of kinesitherapy in patients after reconstruction of ACL, will speed up the recovery of the suppressed by the injury isometric strength endurance of the main knee extensor m.quadriceps, and will create conditions for earlier and more intense development of the indicated mobility.

Aim of the study
Establishing changes in the strength endurance of m.quadriceps femoris in patients after reconstruction of the anterior cruciate ligament, after an experimental kinesitherapy has been applied.

Tasks of the study
a) Establishing the condition of the static strength endurance of m.quadriceps femoris in patients from the control and the experimental group, before applying kinesitherapy;
b) conducting a ten-day kinesitherapy course of in the control and experimental group;
c) establishing the recovery rate of the static strength endurance of m.quadriceps femoris of patients;
d) establishing the efficiency of the experimental model of kinesitherapy.

Methods of the study
a) analysis of literature and other sources;
b) testing;
c) experiment;
d) mathematical and statistical methods.

Subjects
The whole number of the tested patients is 63, 31 of them are included in the control and 32 in the experimental group. Two of the patients do not practice any sports. All patients have signed a Statement of Informed consent for the research, which has been in accordance with the ethical standards, set out in the Declaration of the World Medical Association 1964 in Helsinki, amended by the World Medical Assembly in 1975 (Tokyo), in 1983 (in Venice) and in 1989 (in Hong Kong), actualized in 2008

Venue of the study
The experiment was carried out at the Military Medical Academy Hospital and the Multifarious Hospital for Active Treatment "St. Sofia" in Sofia, Bulgaria.

Description of the experiment
To achieve the aim and the set goals a testing of the static power endurance of m.quadricepsfemorisin the patients of the control and the experimental has been conducted, before applying kinesitherapy. The test is a classic for diagnostic in kinesitherapy. For this purpose the patient is in starting position occipital lying position with the injured leg raised 30 centimeters (the leg is stretched). Next is a retention—until failure. The duration of the muscular effort and tension of m.quadriceps is recorded. In the indicated situation the patient (in the occipital lying position - the leg up to 30 cm.), the hip joint is flexed to 150°, the knee joint is inflexed and ankle joint is loosely laid.

Programs of Physiotherapy
The program of kinesitherapy in the control group was based on the already set standards while for the experimental group an experimental model was developed, which includes:

a) cryotherapy;
b) recovery of the motor walking stereotype, normalization of the workload of the damaged limb, normalization of the locomotor abilities of the patients and neutralization of the adaptive pathological walking changes;
c) manual soft-tissue mobilization following J.C.Terrier aiming at the recovery of the myo-articular mobility, a pain-relieving effect and reducing the edema of the knee joint J.Terrier, (1996), L.Krajdijikova,(2007), L.Kraydijikova et al.(2014), T.Krstev,(2015);
d) kinesio-taping for pain relief and drainage effect aiming at improving the muscle and joint mobility;
e) analytical training for checking the strength of the operated limb including new complexes for enhancing the explosive power, for static and dynamic strength resilience combined complexes for other motor abilities;
f) proprioceptive training using new complexes of exercises with and without appliances for balance, equilibrium, for proprioceptive sensibility and neuro-muscular control and for increasing the dynamic joint and muscle stability) M.Gramatikova, St.Mitova, D.Popova, (2015);
dynamic aquatherapy for enhancing the muscle strength and endurance, for increasing the volume of motion, reducing the muscle spasticity, as well as the edema and pain, and for increasing the mio-articular dynamic stability M.Gramatikova (2015).

It is important to note that in the accessible sources for three of the physiotherapeutic techniques listed above, namely the soft tissue manual mobilization after Terrier, the use of kinesiotape, and dynamic aquatherapy we have not found a developed program that has been applied after an operation on the anterior cruciate ligament of the knee joint. In summary, the applied physiotherapeutical means in the experimental group included kinesio-taping; cryotherapy; manual soft tissue mobilization after J.C.Terrier; Theraband system; fitball; elastic bands; board stones; balance board; mechanotherapy including leg press, multifunctional gladiator, treadmill, exercise bike; analytical gymnastics and aquatherapy. Most of these means used in the course of the recovery treatment of patients after an operation on the anterior cruciate ligament of the knee joint due to injury are either new or updated. The verification of the scientific generalizations is ensured by the attached evidential materials; the methods of mathematical statistics (variance and alternative), the optimal number of the subjects tested and the high reliability of the applied test.

Means of physical therapy in the experimental group

a) cryotherapy;
b) manual soft-tissue mobilization by J.C.Terrier
c) kinesio-taping
d) proprioceptive workout - Thera brand system: elastic bands, a fitball, balance board multi-active stones, a trampoline
e) analytical workout- various dosed exercise, isometric and isotonic resistive in aerobic mode, passive and active, stretching exercises, strength and endurance without and with appliances (fitball, elastic bands), training devices (leg press, treadmill, stationary bike), in an open and closed kinematic chain;
f) aqua therapy- an underwater stationery bike

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As stated above, during the ten-day targeted impact, the aim of kinesitherapy was restoring arthrokineamatics and dynamic joint stability, restoration of myo-articular dysfunction due to surgery and Hypokinesia, restoration of functional abilities of the patients, and their return to their daily work, sports and other activities. The methodology of the applied physical therapy includes methods, means and organizational forms the realization of the targeted impacts with content and structure of the performed procedures, dosage of impact and methodological guidelines for its application. The most commonly applied methods of physical exertion to improve the strength of patients are the repetitive and the uniform methods. The repetitive is the predominant method, the impact is by multiple repetitions of the planned mobility actions with a slow temp or static - in the series, with a break between sets. The dosage of the effects is done by changing the number of repetitions, increasing the amplitude of the driving action by the inclusion of external resistors (different weights), the use of simulators, static or slow exercises with elastic bands etc., as well as by changing of starting positions and change the duration of physical impact. The organizational forms of kinesitherapy are boiled down to:

a. procedures conducted by a kinesiotherapist;
b. aqua therapy conducted by a kinesiotherapist;
c. private activities at home, by prescription.

Developing an individual program of kinesitherapy is mandatory after functional assessment of the patient’s condition, according to pathokinesiology and patho functional features of the moderate - protective period after reconstruction of ACL of the knee joint.

Results

In order to explore the possibilities of these patients to show static strength endurance of m.quadriceps femoris in moderate-protective recovery period of knee complex, we conducted this study. Analyzed are the average difference of values in seconds of the still positon of the damaged (then the healthy leg) in a raised position of 30 cm, until a refusal, at full extension of the knee.

In the control group

The results obtained show that during the first day of the study, in patients in the control group the difference in static strength endurance of m.quadriceps of the healthy and damaged knee is 96.19 + 10.36 sec. (Table 1). This shows that despite being in a second postoperative month, the motor function after conducted knee surgery is very difficult.

After applied ten-day physical therapy, results improved by 37.6% or the difference between the healthy and the operated leg is 60.03 + 8.81 sec or improvement in absolute values of the indicator is 36.16 sec. This shows that the conditions are created for a significant recovery of the available but suppressed by swelling and pain in the knee isometric strength endurance of massive protractor m.quadriceps femoris, which negative factors are neutralized and create conditions for the early development of the said mobility of the stated muscle.

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In the experimental group the baseline of the knee in terms of research indicator is also negative. The average difference in isometric strength endurance of both feet during the first survey was 91.16 + 9.07 sec, but due to the applied experimental model of kinesitherapy it decreases to 16.25 + 4.28 sec. Or restoration of mobility, which is an indicator of the overall condition of the knee is 82.17%. In absolute terms the difference in mobility of healthy and damaged leg has been decreased by 74.91 sec., which clearly speaks about the effectiveness of the developed and implemented experimental model of kinesitherapy for patients at the experimental group. Table 1 shows also that the values of SD at baseline and final study in both groups are high - from 57.7 seconds in the first study in the control group and decreases to 49.1 seconds in the second study. In the experimental group SD decreased from 51.32 sec. to 24.24 seconds, as the tendency is kept, but the changes are more significant and more favorable.

Table 1. Difference in the duration of display of static strength endurance of the healthy and damaged leg (from occipital lying - raised to 30 centimeters until failure in seconds.)

<table>
<thead>
<tr>
<th>Indications</th>
<th>Control group</th>
<th>Experimental group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Difference healthy-injured leg (in seconds)</strong></td>
<td><strong>D</strong></td>
<td><strong>D %</strong></td>
</tr>
<tr>
<td>During day 1</td>
<td>96.1 9</td>
<td>60.03 3</td>
</tr>
<tr>
<td>During day 10</td>
<td>57.6 7</td>
<td>49.06 6</td>
</tr>
<tr>
<td><strong>m</strong></td>
<td>10.3 6</td>
<td>8.81 9</td>
</tr>
<tr>
<td><strong>V%</strong></td>
<td>59.9 5</td>
<td>81.72 6</td>
</tr>
<tr>
<td><strong>A</strong></td>
<td>0.06 9</td>
<td>0.570 6</td>
</tr>
<tr>
<td><strong>E</strong></td>
<td>0.64 2</td>
<td>0.703 6</td>
</tr>
</tbody>
</table>

Regarding the variability of the results, the values of V% show high individual differences in baseline indicators as V% = 59, 95 in the control group - before applying kinesitherapy and increases to 81.72% in the tenth day. In the experimental group to the tendency is similar, as V% from 56, 30% at the beginning of the test, reaches 149, 17% in the tenth day. These trends show increasing variance in the intensity of recovery of the static strength endurance of the main extensor of the knee of the examined patients (m.quadriceps femoris), which requires a deepening of the individual approach in developing mobility of that muscle.

**Gender differences in the recovery of isometric strength endurance**

Another aspect of the research is the study of gender characteristics in restoring power endurance m.quadriceps.

Figure 1 reflects the status and changes in mobility under the influence of the applied two models of kinesitherapy. It is clear the significant difference in the baseline in motor abilities of the injured leg, in both sexes and at the plight of women who established an average difference in isometric strength endurance of the healthy and damaged leg of 134.4 sec. Following the applied traditional kinesitherapy the results in both sexes in the control group improved- for males with 31,62sec, and for females with 45.7 sec.

In the experimental group the results are analogous - high gender differences in the first study, especially in women. As a result of applied experimental model of kinesitherapy the differences in strength endurance of the m.quadriceps of the healthy and damaged leg
decreased on average by 33.04 sec. in men and 81.57 seconds in women. In relative terms the improvement in males is 60% and 80, 7% in females.

**Statistical significance of differences in results**

Regarding the effectiveness of the experimental model of kinesitherapy, due to the type of the data, their measurement (jumps) and numerical characteristics (A and E with values outside the range (-1, 1) while checking the hypotheses of the existence of statistically significant differences between the control and experimental group research with indicator, in the first and tenth day (before and after application of kinesitherapy) used criteria by the Mann Whitney for independent samples, with a probability of an error $\alpha = 0.05$.

<table>
<thead>
<tr>
<th>Variab le</th>
<th>CG- X1</th>
<th>S1</th>
<th>EG-X2</th>
<th>S2</th>
<th>P- value</th>
<th>$D = X_2 - X_1$ (in absolute numbers)</th>
<th>D%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>96,194</td>
<td>57,669</td>
<td>91,15 6</td>
<td>51,31 6</td>
<td>0.559</td>
<td>5,037</td>
<td>5,237</td>
</tr>
<tr>
<td>Day 10</td>
<td>60,032</td>
<td>49,059</td>
<td>16,25 0</td>
<td>24,24 1</td>
<td>0.000</td>
<td>43,782</td>
<td>72,931</td>
</tr>
</tbody>
</table>

P-values show that within regards of research indicator when testing on the first day there was no significant difference in the results of the control and experimental group - $P = 0.559$. On the tenth day $P < 0.05$ or a statistically significant difference in the results in favor of the experimental group, indicating higher efficiency of the applicate model of the kinesitherapy in the recovery of isometric strength endurance of the damaged leg after reconstruction ACL knee joint.

**Discussion and conclusion**

From the average values of the differences in the static strength endurance of healthy and damaged leg is apparent, that during the first day of the study - before the application of kinesitherapy, patients from the control and the experimental group show difficulties in maintaining the position of the leg (extended) in the set position. Difficulties arise from need to overcome the resistance of the weight of the injured limb and because biomechanically the lifted foot is bar of the second type, which requires greater force. The main negative factor, however, is hypotrophy of the ventral and dorsal femoral and crural muscles, the length of the leg (the bar), and other factors. In patients after reconstruction of ACL, the opening of the knee and keeping the set position of the leg is complicated by the involvement of large muscle groups of the lower limb and besides the inclusion of the knee joint also including the hip one. When lifting the leg at first are included m.gastrocnemiius, m.tibialis posterior, and m.flexorhallucislongus. In the second phase - in holding the leg - lifted - in the stretched position, with priority is included m.quadriceps femoris, acting as the main extensor of the knee joint. Simultaneously activate m.biceps femoris and m.gastrocnemiius, further contributing for extending the limb D.Dimitrov,(2003). To retain the set position, the muscles act both synergistic and antagonistic - isometric, which requires inclusion in programs for physiotherapy to develop isometric strength endurance of those muscles, which will intensify the recovery process of the patients. The isometry assists the basic human activities and should be a part of immanent kinesitherapy associated with recovery of motor function of the body and its parts after injuries. It is applied in everyday life - while preserving the various positions of the body for an extended period of time in natural-applied, sports- preparatory and other mobility actions, related to household, sports, labor, entertainment and other human activities. Because of the fact that isometry consumes less energy than isotonic mobility actions and is lighter on the nervous system of the patients its spared inclusion in the kinesitherapeutic program improves its efficiency, but this should not be at the expense of the other targeted impacts. Or we recommend isometry with volume up to 10% of the kinesitherapeutic program and depending on the severity and the nature of the damage.Furthermore, in relation to process of accommodation (adaptation) after the system isometry occurring after 1.5-2 months of implementation, its inclusion in the program of physiotherapy and in the process of the process of self-recovery is episodically alternated with isotonic exercises, according to the trauma and the stage of recovery of the patients.

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OPORAVAK IZDRŽLJIVOSTI SNAGE M.QUADRICEPSA FEMORISA KINEZITERAPIJOM NAKON REKONSTRUKCIJE ACL-a

Sažetak
Provedeno je istraživanje o efektivnosti dvaju programa kineziterapije - tradicionalnog i eksperimentalnog. Utvrđeno je razdoblje za početak oporavka izdržljivosti izometričke snage m.quadricepsa femorisa nakon rekonstrukcije prednjeg križnog ligamenta. Oporavak u drugom postoperativnom mjesecu je povezan sa smanjenjem negativnih faktora da bi se prikazalo dostupno, no otežano u izdržljivost snage, zbog boli, oteklina, recipročnosti mišića i drugih faktora. Testiranje se održalo prije i poslije deset dana kineziterapije. Uspostavljena je razlika u sekundama u izdržljivosti snage m.quadricepsa zdrave i oštećene noge prvog dana u kontrolnoj skupini od 96.19 ± 10.36 sekundi kroz test "o okcipitalnoj nozi - dizanje do 30 cm istegnutih nogi i održavanje". Nakon kineziterapije rezultati su poboljšani za 37, 6% i razlika između dvije noge je smanjena na 60, 03+8, 81 sekundi. U eksperimentalnoj skupini rezultati u izdržljivosti snage m.quadricepsa dvije noge su bili 91, 16+9, 07 pri prvoj procjeni, dok je nakon kineziterapije 16, 25+4, 28 sekundi. U prvom istraživanju P=0,559 a u posljednjem P=0,000, što ukazuje na visoku efikasnost eksperimentalnog modela fizioterapije i njegovu sposobnost za stvaranje uvjeta za rani početak oporavka izdržljivosti snage operiranog noge i njen kasniji razvoj.

Ključne riječi: kineziterapija, zglob koljena, ACL, rehabilitacija, izometrička izdržljivost snage
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