
DIAGNOSTIC SYSTEM FOR FUNCTIONAL ASSESSMENT OF PATIENTS WITH THE O'DONOGHUE TRIAD

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Abstract: One of the most severe and slowly recovering injuries of the musculoskeletal system is the "O'Donoghue Triad" or the so-called "Unhappy Triad". It mainly affects athletes, excluding them for a long time from their sports activities. O'Donoghue's triad includes rupture of the anterior cruciate ligament, rupture of the medial meniscus and rupture of the medial collateral ligament of the knee joint. Immediately after the injury there is static and dynamic instability of the knee joint, which hides a high risk of dislocation of the knee and damage to other tissues: rupture of the joint capsule, rupture of the chondral tissue, rupture of the lateral collateral ligament, damage to the lateral meniscus and others. The treatment is surgical and solves the problem of static instability immediately after surgery. Dynamic instability of the knee joint is restored over a long period of time by applying an analytically designed kinesitherapy program to patients after surgical treatment of the O'Donoghue Triad. For functional assessment and monitoring of the dynamics of recovery and correction of kinesitherapy, it is necessary to make an analytical selection of a test battery from functional indicators and tests corresponding to the dysfunctions of the operated knee. **Purpose:** The purpose of this study is to develop a diagnostic system for functional assessment of patients after surgical treatment of the O'Donoghue Triad. **Research methodology:** To realize the purpose of the research the following methods are applied: Analysis of literature sources (deductive method); Expert evaluation. **Results:** To establish the condition of various aspects of the knee recovery process, after analysis of literature sources and expert assessment in the diagnostic system for functional assessment include: for pain testing: quantitative measurement of pain on a visual-analog scale (VAS - from 0 to 10); goniometry, a method for measuring the range of motion in the knee joint, taking into account the results of the standard SFTR methodology; centimeter - a method for measuring the circumference of the lower limbs in centimeters; manual-muscular testing of the main muscles in the area of the knee complex, examination for the establishment of hypertensive and shortened muscles; test to study changes in the stability of the support; test for static muscular endurance of the sciatic muscles; static muscle endurance test of m. quadriceps femoris; test for assessment of the dynamic strength of the lower limbs (author's test); test for diagnosis of the explosive force of the lower extremities; scale for functional assessment of the condition of the knee joint; study of the locomotor abilities of patients. **Conclusion:** For functional assessment of the condition of the knee joint, a selection of functional tests has been made, prepared as a diagnostic system for functional assessment and for monitoring the dynamics of recovery of the knee complex in patients with "O'Donoghue's Triad" treated surgically.

Keywords: unhappy triad, knee surgery, kinesitherapy, test

1. INTRODUCTION

Knee injuries are among the most common injuries of the musculoskeletal system. This is determined by the mass involvement in sports - professionally and as a hobby. The practice of football, alpine skiing, tennis, basketball, etc., are a prerequisite for trauma to the soft tissue structures of the knee complex from sprains to ruptures (anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), meniscus, capsular-ligamentous, often medial collateral ligament (MCL), musculoskeletal structures, patellar luxation, etc.), as well as cause intra-articular fractures and patellar fracture. The "Unhappy triad" of injuries to the knee is actually a tetrad involving not just the ACL, MCL, and medial/lateral meniscus but also involved the anterolateral complex, early phase of the injury the knee is forced into internal rotation (Ferretti, Monaco, Ponzio, et al., 2019). We conclude that the classic O'Donoghue triad is, in fact, an unusual clinical entity among athletes with knee injuries; it might be more accurately described as a triad consisting of ACL, MCL, and lateral meniscus tears. This injury combination appears to be more common when an incomplete, or second-degree, tear of the medial collateral has occurred (Shelbourne, Nitz, 1991). The "O'Donoghue triad" is one of the most serious sports injuries. Most cases require surgery and a recovery period of six to nine months. Recognition and repair of the ALL lesions should be considered to improve the control of rotational stability provided by ACL reconstruction. For high-risk patients, a combined ACL and ALL reconstruction improves rotational control and reduces the rate of re-rupture, without increased postoperative complication rates compared to ACL-only reconstruction (Sonnerly-Cottet, Daggett, Fayard, et al., 2017).

Immediately after the trauma "Unhappy triad" is observed: swelling, hemorrhage, serous effusion, which form after hours and accompany the meniscal and ligament injuries. In the acute phase there is pain, impaired muscle control,

edema, reflex muscle inhibition. Hypokinesia and immobilization of the knee complex, as a result of surgical interventions, cause restriction of joint mobility. Restriction of joint mobility after a few weeks of immobilization develops due to the adaptive shortening of the soft surrounding tissues: joint capsule, ligaments, musculoskeletal structures. Another reason for the disturbed arthrokinematics in knee is the growth of fibrous tissue, which, by limiting the caudal sliding of the patella, limits the flexion. If it restricts the cranial sliding of the patella, it also limits the extension of the knee. With limited flexion, below 50°, there are difficulties in the swinging phase when walking, as the injured limb cannot be shortened enough to move forward. It is manifested by compensatory mechanisms during the gait in the swing phase: elevation of the pelvis and inclination of the carcass in the opposite direction; lifting fingers on the unaffected limb; bringing the limb forward in an arc, by circumduction, instead of in a straight line by flexion (mowing gait).

Limited extension in knee is a characteristic pathobiomechanical change, affecting posture and locomotor ability (the impossibility of full extension in knee causes relative shortening of the lower limb and compensatory depression of the pelvis during the support phase, with support supported by fingers rather than toes. The reasons may be: increased passive resistance (contractures and adhesions) caused by shortening of the flexors, shortening of the ACL, shortening of the dorsal joint capsule or collateral ligaments; reduced strength of *m. quadriceps femoris* caused by malnutrition, pain or swelling; disrupted arthrokinematics: caused by limited "screw" rotation at the end of the extension impossible "locking" of the knee; limited ventral sliding of the tibia; limited cranial sliding of the patella; blockage of the intra-articular body.

After arthroscopic restoration of the knee, mechanical pain is established, which complicates the recovery process. It limits the range of motion (Glushkova, Nikolova, Glushkov, et al., 2014), causes reflex muscle inhibition, limits the load on the operated leg with the weight of the body. It is one of the factors for impaired locomotor ability, causing claudication. Patients limit their functional abilities for fear of causing or increasing pain. Mechanical pain is caused by lymphostasis, which compresses nociceptors, provoking pain perception. This is not a pathological problem, but a mechanical one, because there are no signs of an inflammatory reaction - the pain is not constant. Swelling and pain as well as their changes are also indicators of the effect and applicability of the remedies. Persistence of these symptoms, however, may delay and limit the use of a number of kinesitherapeutic agents. Pain and swelling lead to reflex muscle inhibition (Mitova, 2015), which in turn leads to adaptive shortening of soft tissues (muscles, ligaments, skin), which lose their contractile ability and limit the range of motion of the knee.

In post-traumatic contractures of the knee joint, the individual thigh muscles react with various pathological changes, depending on their function. While *m. vastus medialis* responds with suppression and hipotonia, *m. rectus femoris* shows a tendency to shorten and hypertonic, as well as *m. gastrocnemius*. Arthrogenic muscle inhibition is a disorder of gamma-motoneuron muscle control and suppresses muscle strength (Avramova, 2020).

After surgical interventions with subsequent immobilization of the knee joint, in patients after O'Donoghue Triad, the main symptoms and dysfunctions of the knee are identified, such as: swelling, pain, reflex muscle inhibition, muscle weakness and malnutrition, muscle imbalance, limited range of motion (Valchev, Gramatikova, Mitova, 2019), impaired gait, dynamic instability, impaired proprioception (Shivachev, Bogomilova, 2020). 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. An important aspect of modern kinesitherapy is the consideration of the effect of the procedure. This is a basic criterion for progression in the methodology, and the direction of the assessment should be based on the fact whether the procedure "holds", "worsens" or "improves" the patient's condition.

All this justifies the creation of a diagnostic system for functional assessment of patients with O'Donoghue Triad, treated surgically, with which to assess the functional abilities and deficits of patients. The diagnostic system and its functional tests and tests will be a leading factor in the progression of the load and the inclusion of new tools in kinesitherapy procedures.

2. MATERIALS AND METHODS

Purpose: The purpose of this study is to develop a diagnostic system for functional assessment of patients after surgical treatment of the O'Donoghue Triad. **Research methodology:** To realize the purpose of the research the following methods are applied: Analysis of literature sources (deductive method); Expert evaluation.

3. RESULTS

Clinical manual diagnostic methods most often used (testing of the static capsule-ligament stability of the knee complex):

Anterior knee instability testing: - Lachman test; - Testing for anterior-lateral rotator instability; - Pivot shift test.

Testing of premedial rotational instability: - Slocum test; - Medial knee instability testing - valgus stress test; - Varus and valgus stress test with full extension in the knee.

The diagnostic system for functional assessment and for determining the condition of various aspects of the knee recovery process in patients after surgical treatment of O'Donoghue Triad, includes the following indicators:

1. Examination of pain:
 - a) Quantitative measurement of pain on a visual-analog scale (VAS - from 0 to 10).
 - b) Analysis of pain - type, location and moment of manifestation.
2. Anglometry, a method for measuring the range of motion in the knee joint, taking into account the results of the standard SFTR method.
3. Centimeter - a method for measuring the circumference of the lower limbs in centimeters.
4. Manual-muscular testing of the strength of the main muscles in the area of the knee complex.
5. Examination to establish hypertonic and shortened muscles.
6. Author's (original) test to study changes in the stability of the support (Gramatikova, 2017).
7. Test for static muscular endurance of the ischiocrural muscles (knee flexors).
8. Static muscle endurance test of *m. quadriceps femoris* (knee extensor).
9. Test for assessment of the dynamic strength of the lower limbs (author's test-(Gramatikova, 2017).
10. Test for diagnosis of the explosive force of the lower limbs.
11. Scale for functional assessment of the condition of the knee joint (Seligson, et al., 1993).
12. Study of the locomotor abilities of patients (Popov, 2009).

Diagnostic system for functional assessment - characteristics of research methods

Pain assessment: - quantitative measurement of pain on an 11-point visual-analog scale (VAS). The patient self-assesses the degree of pain, which is reported in absolute value from 0 to 10. Every day we examine the degree and features of pain, which information supports the selection and dosage of kinesitherapeutic agents; - **the qualitative analysis** (features) of the pain provocation at passive research of the joint mobility and at active movements, is applied, for specification of the factors causing it. We classify it according to the moment of manifestation (at rest, during movement, at the end of the movement, after additional pressure), according to the type (pulling, sharp). We examine pain and always associate it with the range of motion, and vice versa.

Anglometry (Gramatikova, Petrov, Pacheva, et al., 2016): the measurement of the active and passive range of motion in the knee joint (flexion and extension) for a healthy and operated leg is performed with a universal two-arm protractor (goniometer), representing a conveyor with a scale of 360°, modified with two long arms. The results of the standard SFTR methodology. The results are reported in degrees. The active range of motion determines the functional capabilities of the operated limb. The study of passive range of motion, in addition to results in degrees, provides information about the final sensation of tissue resistance, pain response and factors limiting movement (such as shortening of the joint capsule, ligaments or muscles) and the choice of appropriate means for their recovery.

Centimeter: the circumferences of the two lower limbs are measured at several levels: through the knee joint (along the joint space); proximal to the patella; distal to the patella, these levels provide information about the presence of edema. At level 8, 18, 28 cm from the proximal edge of the patella; through the widest part of *m. triceps surae*, these levels are an indicator of the presence of muscular malnutrition. The centimeter is placed on the middle part of *m. vastus medialis* (at 8 cm), at *m. rectus femoris* (18 cm) and *m. adductor longus* (at 28 cm). The measurement is performed with a plastic centimeter, the results are reported in centimeters.

Manual-muscular testing of the main muscles in the area of the knee complex: this method allows for maximum analytical and reliable examination and assessment of the degree of muscle weakness caused by immobilization, pain, reflex muscle inhibition, hypodynamics, gentle motor mode, muscular imbalance, etc. The degree of muscle strength (weakness) is examined according to the standard methodology in 6 main degrees from 0 to 5. The operated and healthy lower limb is examined. The method of manual-muscle testing examines the muscles: *m. quadriceps femoris* and *m. rectus femoris* (extensors in the knee complex). Starting position - occipital leg. The patient has an extended knee. Lifting the leg (flexion in hip joint) against manual resistance applied by the therapist. *M. vastus medialis* (extensor in the knee complex, medial patellofemoral stabilizer). Starting position - occipital leg. The patient has an extended knee and external rotation in the hip joint. Lifting the leg (flexion with external rotation in hip joint) against manual resistance applied by the therapist. *M. vastus lateralis* (extensor in the knee complex, lateral patello - femoral stabilizer). Starting position - occipital leg. The patient has an extended knee and internal rotation in the hip joint. Lifting the leg (flexion with internal rotation in hip joint) against manual resistance applied by the therapist. *M. biceps femoris* (knee flexor and axial external tibial rotator). Starting position - face lying down. The patient performs flexion in the knee with external rotation in the lower leg, against manual resistance applied by the therapist. *M. semitendinosus* et *m. semimembranosus* (knee flexors and axial internal rotators of the lower leg).

Starting position - face lying down. The patient performs flexion in the knee with internal rotation in the lower leg, against manual resistance applied by the therapist. ***M. biceps femoris***, ***semitendinosus*** and ***m. semimembranosus*** (knee flexors). Starting position - face lying down. The patient performs flexion in the knee, against manual resistance applied by the therapist. ***M. tensor fasciae latae*** (flexor from 45° to 145°, lateral tibio-femoral and patello-femoral stabilizer (via TIT)). Starting position - lateral leg. The patient has an extended knee. Lifting the leg (abduction and internal rotation in hip) against manual resistance applied by the therapist.

Establish hypertensive and shortened muscles: To establish hypertensive and shortened muscles of the knee complex, palpation is applied. At the end of the possible range of motion (in flexion and extension), if the stretched myotendinous structure is tense and hypertonic, this is the main factor limiting physiological movement.

Assessment of the stability of the support (author's test (Gramatikova, Mitova, Popova, 2015): After checking its reliability with a test-retest and an established correlation coefficient $r_{tt} > 0.7$, the test was tested. Serves to assess changes in the stability of the support of the injured lower limb. It is also indicative of the effectiveness of the applied restorative kinesitherapy methodology, as well as provides an opportunity for accurate quantitative measurement of the intensity of the recovery process of the knee. **The test is applicable to any damage to the lower extremities.** It is expressed in the simultaneous stepping of two identical mini-platforms, taking into account the absolute values (in kg) of body weight assumed by the healthy and injured leg and the changes in the ratio during the recovery period. The simultaneous pressure of both limbs is measured and the differences are determined. To perform the test, follow the instructions to the patient "Please step firmly on both feet on the platforms, stand still and look ahead!", Then wait 20-25 seconds. to stabilize the values.



Evaluation of static muscular endurance of *m. quadriceps femoris*: from the occipital leg, the patient raises the test lower limb 30 cm from the support, which is extended in the knee. The retention time in the set position of the lower limb is read, until failure (in sec.). The normative limit of 4 minutes (240 sec) was adopted during the measurements. The test is performed for the operated and for the healthy lower limb.

Assessment of static muscular endurance of the sciatic muscles: in the test the patient is in faces lay down, the lower leg of the injured leg is raised to 30 cm. from the support, performing flexion in the knee and holding in the set position until failure. Here, too, a normative limit of 4 minutes (240 sec) is adopted in the measurements. The test is performed for a healthy and operated lower limb.

Assessment of the dynamic strength of the lower limbs (author's test, (Gramatikova, 2017): Testing of the dynamic strength of patients with limited amplitude motor action, including repeated performance with a maximum rate of motor action "standing - sitting (on a fixed chair, height-adjustable) - standing", performed for 30 seconds, taking into account the maximum number of motor actions (number of cycles). When sitting - hip, knee and ankle joint are in flexion 90°, by adjusting the height of the support.



Assessment of the explosive power of the lower limbs (Gramatikova, Mitova, Glushkov, et al., 2016): the test establishes the ability of patients to perform a vertical jump. The patient faces the wall and next to it. He raises one arm up and touches the wall, trying to keep it as high as possible. Place a ruler over the first point of contact and hold it. The patient then lowers his arm and relaxes. We give instructions that he should bounce vertically upwards and touch the wall with his hand as high as possible above the first point. We read on the ruler the rebound in cm (the distance between the first and second point of contact). The test is performed in patients who have a score of at least (4) on Manual-muscular testing (MMT) for the strength of ischiocrural and *m.quadriceps femoris* muscles. To prevent patients from compromising the reconstructed ACL and after consultation with an orthopedic surgeon, we concluded that to protect patients from risk, the threshold for this test is a score (4) on MMT, which determines sufficient dynamic joint and muscle stability, to perform the test. The test is identical for strength and dynamic stability of the knee.

Functional assessment of the condition of the knee joint (on a rating scale) (Seligson, et al., 1993): The scale includes different categories of questions that answer a different symptom: pain, myo-articular stability, the presence and appearance of edema, range of motion, functional activity. Each question on the scale has variants of different answers that carry a different number of points. The patient answers the questionnaire himself, after which the result is reported, summing up the points of the respective answers. The maximum score is 20 and the minimum is 0. Grades 19 and 20 are reported as excellent results, grades 15-19 for good results. A score below 15 determines the presence of risk in sports activities and the development of chronic joint instability. The scale is used for comparative analysis of changes in the functional capabilities of patients before and after the application of kinesitherapy.

Examination of locomotor abilities without aids: the examination is performed by measuring the following indicators: - **number of steps to overcome a distance of 10 meters.** On level ground, a distance of 10 meters is measured with a tape measure, the patient walks the distance, walking without aids; - **stride length** with the operated lower limb. On level ground we mark the starting line. The patient stands behind her, with the toes on the line. The patient takes a step forward with the injured leg. Measure the distance from the line to the heel with a tape measure and read the result in centimeters. He returns to the starting position, then takes a step and with a strong leg, we again report the result in centimeters.

4. DISCUSSION

At the beginning of active kinesitherapy, exercises in the closed kinetic chain are applied, in contrast to those in the open kinetic chain. Resistive exercises (especially with a long bone lever) from 0° to 30° flexion are not recommended due to the thus induced ventral translation and loading of the graft, as there is a risk of rupture or overstretching of the reconstructed anterior cruciate ligament. Therefore, the manual muscle strength test of *m. quadriceps femoris* and *m. rectus femoris* was modified and applied with an extended knee, not the standard method.

5. CONCLUSION

For functional assessment of the condition of the knee joint, a selection of functional tests has been made, prepared as a diagnostic system for functional assessment and for monitoring the dynamics of recovery of the knee complex in patients with "O'Donoghue's Triad" treated surgically.

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