ANALYSIS OF MOTOR COORDINATION ALTERATION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

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ABSTRACT

Research background and hypothesis. The Anterior cruciate ligament (ACL) is the most commonly injured ligament of the knee and its injuries result in significant functional impairment. Injury to the ACL is associated with altered knee joint loading and impaired neuromuscular control, which defined as the ability to produce well controlled movements and dynamic balance.

Research aim. The aim of this study was to evaluate motor coordination and functional capacity of patients who received rehabilitation program following ACL reconstruction.

Research methods. The study included 15 males aged 33.7 ± 2.49 years who had undergone unilateral ACL reconstruction with a semitendinosus/gracilis (STG) graft in Kaunas Clinical hospital. For objective functional testing, we used figure-of-eight movement coordination test. The Lysholm questionnaire was included as a disability outcome measure following ACL injury and reconstruction. The patients were assessed preoperatively and after 5 and 21weeks postoperatively.

Research results. The results of this study indicated that motor coordination timescale showed significant differences ($p < 0.05$) between the injured and the healthy legs before surgery and after 5 and 21 weeks. The movement coordination test data showed that there the timescale significantly longer on the injured knee compared with the noninjured knee. After 21 weeks of rehabilitation we found significantly lower ($p < 0.05$) values in injured knees compared with the preoperative data. In injured knee the timescale after 21 weeks of rehabilitation was significantly ($p < 0.05$) longer compared with noninjured knee.

The Lysholm questionnaire scale indicated that there was a significant difference in the results for values ($p < 0.05$) before surgery and after 21 weeks of rehabilitation. The questionnaire scale data showed that after 21 weeks of rehabilitation results for values was significantly ($p < 0.05$) highest compared with before surgery and after 5 weeks.

Discussion and conclusions. There was improvement in the injured leg in mean motor coordination timescale 21 weeks after ACL reconstruction, but the timescale was higher than in the uninjured leg. After 21 weeks of ACL reconstruction knee functional status in most patients was good or excellent.

Keywords: knee joint, the Lysholm questionnaire, movement coordination test.

INTRODUCTION

Powerful, precise, controlled movements are an integral part of sports activities and daily functional activities (Myer et al., 2006). The Anterior cruciate ligament (ACL) is the most commonly injured ligament of the knee and its injuries result in significant functional impairment (Krych et al., 2008; Kessler et al., 2008; Almqvist et al., 2009). Injury to the ACL is associated with altered knee joint loading and impaired neuromuscular control, defined as the ability to produce well controlled movements and dynamic balance (Risberg et al., 2004;

Ageberg, 2002). All these deficiencies contribute to the development of osteoarthritis and ACL re-injury (Lohmander et al., 2007). The ACL injury is commonly managed by orthopaedic surgeons, physical therapists, and athletic trainers. A variety of surgical techniques and rehabilitation protocols is used to treat the ACL injury. Knee surgery may alter the neuromuscular response to unexpected perturbations during functional, dynamic tasks. After surgery, knee function recovery depends on many factors, including muscle control and coordination, muscle contraction speed, effort, imbalances between the two legs **(**Krych et al., 2008). The rehabilitation usually emphasises normalisation of bilateral symmetries in joint mobility, motion and neuromuscular control, muscle strength, and functional activity (D'Amato, Bach, 2003). The underlying problem must be identified and addressed during rehabilitation if the athlete is to return to participation at the preinjury level (Voight, Cook, 1996). Functional performance based evaluation is important to assess the effectiveness of surgery, rehabilitation and individual assessment of progres. Function in subjects with ACL injury may be evaluated with self-reported outcome scores (Gustavsson et al., 2006; Risberg et al., 2004; Lysholm, Gillquist, 1982). Motor coordination is one of the factors creating a functional knee joint stability (Myer et al., 2006).

All voluntary movements are controlled by the central nervous system. The so-called "team", i. e. nerve impulses sent to muscles, strength, order and harmony, are awarded with the information from the integrated analysis of multiple receptors (Poderys, 2004). It has been found that the management of complex movements requires coordination of many muscles (Kelso, 1999). Therefore, it may form a temporary coordination structure which works as a cohesive whole. One of the 10 principles of biomechanics that affect movement control is coordination principle – it shows the ability of the body or its parts to co-ordinate with the environment and oneself. The human body is a physiological system that is capable of achieving (central nervous system support) the desired time, speed, acceleration, and a peak movement. This principle has been studied the least (Skurvydas, 2008). The aim of this study was to evaluate motor coordination and functional capacity of patients who received a rehabilitation program following ACL reconstruction. We hypothesized the following: After 21weeks of ACL reconstruction and reabilitation knee function assessed by motor coordination and self-assessment questionnaires would significantly improve.

RESEARCH METHODS

Subjects. The research sample included 15 males aged 33.7 ± 2.49 years, body weight 78.93 ± 4.31 kg, height 177.93 ± 3.37 cm (mean ± SD) who had a diagnosis of ACL rupture. Inclusion criteria were: 1) unilateral, non-acute ACL deficiency without associated lesions of other structures of the knee, 2) an uninjured contralateral extremity, back and neck, and 3) no history of neurological, metabolic disease, vestibular or visual disturbance, knee, ankle, and hip osteoarthritis. This patients had undergone unilateral ACL reconstruction with a semitendinosus/gracilis (STG) graft in Kaunas Clinical Hospital. All subjects followed the traditional rehabilitation program for ACL reconstruction. Rehabilitation goal was to increase the knee range of motion and muscle strength, develop balance and proprioception. The patients were assessed preoperatively and at 5 and 21weeks postoperatively. The uninjured contralateral knees of these patients were used as an internal control.

Each subject read and signed a written informed consent form consistent with the principles outlined in the Declaration of Helsinki. All subjects gave informed consent according to the requirements of the Kaunas Regional Ethics Committee of Biomedical Research (Protocol No. BE-2-30).

Assessment of motor coordination. For objective functional testing, we used figure-of-eight movement coordination test. The floor was marked by two parallel lines, 5 cm apart from each other. Two stamens were put on one line 40 cm apart from each other. The subject stood sideways to the stamens with both feet on the line without stamens. The subject was asked to perform five figure-of-eight movements as fast as possible around the stamens and put the leg to the starting position on the line (Poderys, 2004). The stopwatch was started concurrently with the starting signal and was stopped when the subject completed the course. The time was recorded in seconds. The test was performed 3 times for each leg with a short resting period between each trial. The means of each limb were calculated and used to determine limb symmetry. Limb symmetry was calculated dividing the mean score of the involved limb by the

score of the uninvolved side and multiplying the result by 100 (D'Amato, Bach, 2003).

Lysholm scale. The Lysholm questionnaire was included as a disability outcome measure following ACL injury and reconstruction. The modified Lysholm scale, as described by Y. Tegner and J. Lysholm (1985), is an eight-item questionnaire that was originally designed to evaluate patients following knee ligament surgery. It is scored on a cumulative 100-point scale (representing normal knee function), with 25 points for knee stability, 25 points for pain, 15 points for locking, 10 points each for swelling and knee function with stair-climbing, and 5 points each for limb, use of a support, and knee function with squatting. The Grading the Lysholm Knee Scoring scale was as follows: excellent condition (95–100 points); good condition (84–94 points); fair condition (65–83 points); poor (< 64 points). This scale has been used extensively in clinical research studies (Lysholm, Gillquist, 1982).

Statistical analysis. Descriptive data are presented as means ± standard deviation (SD). Data were analyzed using a repeated measure analysis of variance (ANOVA) with time as the repeated measure factor for the outcome measures at the 5 and 21-weeks follow-ups. SPSS (SPSS Inc., Version 10.0, Chicago, IL) was used to calculate the ICC. A difference between injured and uninjured knee was analyzed using one way ANOVA. The t-test for paired samples was used to determine whether there was a difference between the mean values for the same measurements on the operated and normal knee joints. The difference of $p < 0.05$ between the means of the same measurements for the operated and normal knees was considered to be statistically significant.

RESEARCH RESULTS

Motor coordination deficits of the knees were determined by measuring the ability of the patient to reproduce functional movement coordination test. The results of this study indicated that motor coordination timescale indicated a significant differences ($p < 0.05$) between the injured and the healthy legs before surgery and after 5 and 21 weeks. The movement coordination test data showed the timescale was significantly longer on the injured knee compared with the uninjured knee. There were significant differences ($p < 0.05$) in both legs after 21 weeks of rehabilitation (Table 1). After 5 weeks after surgery we found higher difference for timescale between legs compared with the values before surgery and 21 weeks after rehabilitation. After 21 weeks of rehabilitation we found significantly lower ($p < 0.05$) values in injured knees compared with the preoperative data. In injured knee, the timescale after 21 weeks of rehabilitation was significantly ($p < 0.05$) longer compared with uninjured knee.

The Lysholm questionnaire scale indicated that there was a significant difference in the values ($p < 0.05$) before surgery and after 21 weeks of rehabilitation. The questionnaire scale data showed that after 21 weeks of rehabilitation the values were significantly ($p < 0.05$) higher (mean values – 89.4 ± 0.35) compared with the ones before surgery (mean values – 65.5 ± 8.7) and after 5 weeks (mean values 62.1 ± 9.2) (Figure). There were no significant differences in the values before surgery and after 5 weeks of rehabilitation (Table 2).

DISCUSSION

The principal role of the anterior cruciate ligament (ACL) is to resist anterior displacement of the tibia on the femur. During the knee extension, it is tense and protects some of knee joint hyperextension. The ACL is strong and stiff, yet because of its unique structure, it is precariously susceptible to injury (Cabaud, 1983). ACL rupture is one of the most common knee pathologies. Then the patient feels the knee to be unstable. ACL reconstruction is of major importance as it maintains knee stability and prevents osteoarthritic alterations which can develop rapidly (Ageberg, 2002). Our study has shown that motor coordination timescale was significantly longer in injured ACL-deficient knee than in the contralateral knee (normal knee) before surgery and after 5 and 21 weeks of rehabilitation. Receptors responsible for detecting movement and providing feedback to the central nervous system are found in the skin, ligaments, joints, muscles and tendons. If receptors or pathways become damaged (after ACL injury), the ability to detect body movement and position is affected. As balance and movements depend on an intact sensorimotor system, functional limitations in activities such as walking and climbing stairs can occur when receptors are damaged or destroyed. Reduced sensation, lower extremity muscle weakness, and damage of receptors can affect motor coordination (Myer et al., 2006).

After 21 weeks of rehabilitation we found significantly lower values in injured knees

Figure. **Changes in Lysholm Functional Scale scores over time ($p < 0.05$)**

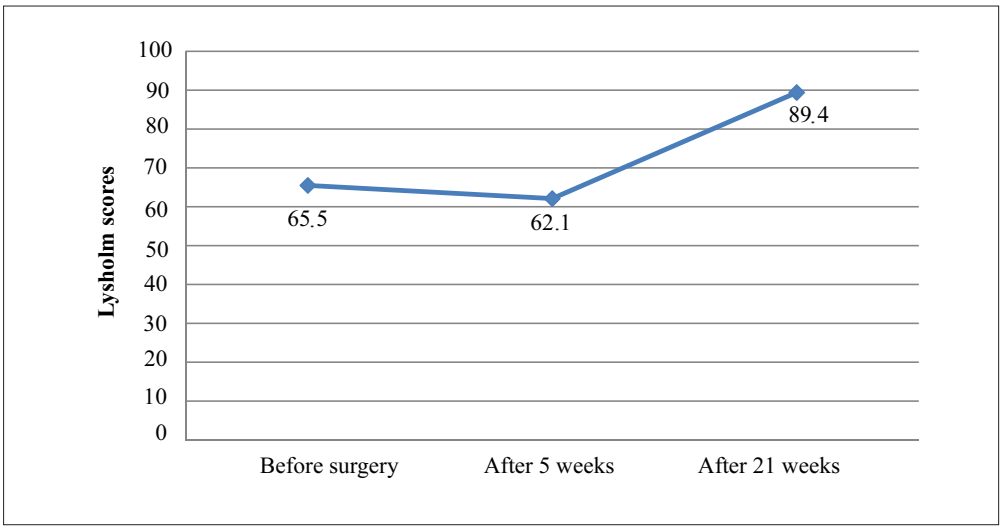

Table 1. **Difference in seconds (%) in movement coordination test for timescale mean (averages ± SD) between injured knee and uninjured knee**

Knee	Before surgery (averages ± SD)	After 5 weeks (averages ± SD)	After 21weeks (averages ± SD)
Injured knee	7.4 ± 1.1	8.6 ± 1.3	6.9 ± 1.1
Uninjured knee	7 ± 0.8	6.7 ± 0.6	6.3 ± 0.46
Difference of s (%)	5.8*	18.2*	7.2*

Note. * – $p < 0.05$, injured and uninjured knee compared.

Table 2. **Lysholm Knee Functional Scale scores (means, SD, percentage (%) and number of patients with knee functional condition)**

Grading Lysholm Knee Functional scale scores	Before surgery		After 5 weeks		After 21 weeks	
	Averages ± SD	Averages % (n)	Averages ± SD	Averages % (n)	Averages ± SD	Averages % (n)
Excellent condition (95–100 points)	–	–	–	–	97.2 ± 2.6*	60% (9)
Good condition (84–94 points)	–	–	–	–	89.6 ± 0.5*	33.3% (5)
Fair condition (65–83 points)	71.7 ± 6.8	67% (10)	68.6 ± 5.1	33.3% (5)	81	6.7% (1)
Poor, < 64 points	59.4 ± 4.8	33.3% (5)	55.6 ± 6.5	67% (10)	–	–

Note. * – $p < 0.05$, compared before surgery and after 21 weeks.

compared with the preoperative data. One of the most interesting questions in neuroscience concerns the manner in which the nervous system can modify its organization and ultimately its function throughout an individual's lifetime based on sensory input, experience, learning and injury (Donoghue et al., 1996) The most advanced motion coordination is based on the interpretation of complex dynamical systems theory. According to the coordination mechanism, the elements of the system depend on the spontaneous self-adjustment movement task, the conditions of the motor system and the specificity of the environment. There is no doubt that this self-adjustment takes place under certain physiological and biomechanical principles or rules which are being intensively studied. Coordination mechanism characterized by the fact that if one element is out of order other try to correct it immediately. There are several well-known main causes of errors in movement performance. Some of them are: a) specific motor programming errors (e.g., excessive movement speed), b) errors in the realization of a specific motor program (for example, influence by muscle

fatigue and weakness, etc.) (Skurvydas, 2008). R. A. Schmidt and T. D. Lee (1999) have suggested that a fast and accurate motion duration is longer when more complex movements by larger muscles are performed. Scientists do not yet know the main reason why more people control movements and change their duration and movement speed. It has been noted that in order to perform precise movements, people tend to choose neither very high nor very low speed, just moderate. Everyone has a particular speed of movement.

Recovery of knee joint function and successful return of the patients to preinjury activities are crucial factors in assessing clinical outcomes. For this purpose, we used the Lysholm score. The rating system of Lysholm questionnaire has been well established, as an alternative mechanism to gather outcomes data when evaluating knee ligament injuries on a disability questionnaire, significant results were shown on subjective scores of disability in ACL reconstructed patients (Williams et al., 1999). We found a significant improvement in Lysholm activity scores postoperatively ($p < 0.05$). H. Ödzemir et al. (1999) and S. Karasel et al. (2010) found similar results following rehabilitation of patients undergoing ACL reconstruction. Our study has shown that the mean Lysholm score for 15 patients after an 21 weeks follow-up was reported to be 89.4.

CONCLUSIONS AND PERSPECTIVES

In conclusion, our study shows that there was an improvement in the injured leg in mean motor coordination timescale 21 weeks after ACL reconstruction, but it was higher than in the uninjured leg. After 21 weeks of ACL reconstruction, achieved knee functional status in most patients was good or excellent.

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JUDESIŲ KOORDINACIJOS POKYČIAI PO PRIEKINIŲ KRYŽMINIŲ RAIŠČIŲ REKONSTRUKCIJOS

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Dažniausiai yra pažeidžiamas kelio sąnario priekinis kryžminis raištis (PKR). Pažeidus PKR, padidėja kelio sąnario apkrovimas ir pablogėja neuroraumeninė kontrolė, kuri apibūdinama kaip gebėjimas gerai kontroliuoti judesius ir dinaminę pusiausvyrą.

Tikslas – nustatyti judesių koordinacijos ir funkcinių gebėjimų pokyčius po atliktos PKR rekonstrukcijos ir reabilitacijos.

Metodai. Buvo tiriama 15 vyrų **(**33,7 ± 2,49 m.), kuriems Kauno klinikinėje ligoninėje atlikta vieno kelio PKR rekonstrukcija panaudojant pusgyslinio/grakščiojo raumens sausgyslės transplantą. Judesių koordinacijai (JK) ištirti naudotas „Kojos mojavimo aštuonetu“ funkcinis testas. Kelio sąnario funkcinei būklei nustatyti buvo naudojamas *Lysholm* klausimynas. Testavimai atlikti prieš operaciją ir praėjus 5 ir 21savaitėms po jos.

Rezultatai. Prieš operaciją bei praėjus 5 ir 21savaitėms po jos pažeistos ir sveikos kojos JK trukmės rezultatai buvo skirtingi, o pažeistos kojos judesių trukmė statistiškai reikšmingai ilgesnė nei sveikos kojos ($p < 0,05$). Praėjus 5 savaitėms po operacijos, JK trukmės rezultatų skirumas tarp sveikos ir traumuotos kojų buvo didžiausias. Praėjus 21 savaitėms po operacijos ($p < 0,05$), pažeistos kojos judesio trukmė statistiškai reikšmingai sutrumpėjo, lyginant su rezultatais prieš operaciją, bet trukmė išliko statistiškai reikšmingai ilgesnė, lyginant su sveika koja ($p < 0.05$). *Lysholm* klausimynas parodė statistiškai reikšmingą rezultatų skirtumą prieš operaciją ir praėjus 21 savaitei po jos ($p < 0,05$). Klausimyno rezultatai po 21 savaitės buvo statistiškai reikšmingai aukščiausi palyginus su rezultatais prieš operaciją ir praėjus 5 savaitėms po jos ($p < 0,05$).

Aptarimas ir išvados. Praėjus 21 savaitei po PKR rekonstrukcijos, pažeistos kojos judesių koordinacija pagerėjo, bet judesio trukmė liko ilgesnė nei sveikos kojos. Daugumos tiriamųjų kelio sąnario funkcijos būklė buvo puiki arba gera.

Raktažodžiai: kelio sąnarys, *Lysholm* klausimynas, judesių koordinacijos testas.

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