

Evaluation of knee joint stability after ACL reconstruction with an ST/GR graft using an Aircast Rolimeter

Ocena stabilności stawu kolanowego po rekonstrukcji ACL przeszczepem ST/GR przy użyciu Rolimeter Aircast

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Słowa kluczowe: niestabilność, rekonstrukcja ACL, rolimetr.

Abstract

Introduction: ACL damage results in instability of the knee joint. It is characterized by abnormal hypermobility leading to repeated injuries of the joint.

Aim of the research: To evaluate the function of the knee joint in relation to mechanical stability and to evaluate the parameters influencing the stability of the knee joint in the period of 3 to 5 years after surgery.

Material and methods: The study enrolled 51 patients, 38 men and 13 women, operated on due to ACL rupture. The knee joint stability was assessed with a Rolimeter and the Lysholm scale, and the isokinetic muscle strength was measured with a Biodex 4 dynamometer. The study was carried out in the period from 3 to 5 years after the operation.

Results: The difference between the Rolimeter measurement of the uninvolved knee and operated one was no more than 3 mm in most of the respondents (84.3%). Joint instability over 3 mm was observed in 15.7% of the respondents. The strength of the extensor muscles of the knee joint was significantly higher in the uninvolved limbs compared to the operated ones.

Conclusions: After ACL reconstruction, some patients have instability in the operated joint. Assessment of the function and instability of the knee joint using the subjective Lysholm scale is comparable to the assessment performed with the objective research tool - the Rolimeter. Patients after arthroscopic ACL reconstruction develop chronic muscle strength disorders.

Streszczenie

Wprowadzenie: Następstwem uszkodzenia ACL jest niestabilność stawu kolanowego. Charakteryzuje się ona nieprawidłową, nadmierną ruchomością, która prowadzi do ponownych urazów stawu.

Cel pracy: Ocena funkcji stawu kolanowego w odniesieniu do stabilności mechanicznej oraz ocena parametrów wpływających na stabilność stawu kolanowego w okresie od 3 do 5 lat od operacji.

Materiał i metody: Materiał badań stanowiło 51 pacjentów, 38 mężczyzn i 13 kobiet, operowanych z powodu zerwania ACL. Średnia wieku badanych to 34,4 ± 7,2 roku. Przeprowadzono ocenę stabilności stawu kolanowego za pomocą rolimetra, ocenę funkcjonalną za pomocą skali Lysholma oraz badanie izokinetyczne siły mięśni prostowników i zginaczy stawu kolanowego za pomocą dynamometru Biodex 4 pro. Badanie przeprowadzono w okresie od 3 do 5 lat od operacji.

Wyniki: U większości badanych (84,3%) różnica pomiędzy pomiarem rolimetrem kolana zdrowego i operowanego wyniosła nie więcej niż 3 mm. Niestabilność stawu powyżej 3 mm zaobserwowano u 15,7% badanych. Siła mięśni prostowników stawu kolanowego jest znacząco wyższa w kończynach zdrowych w porównaniu z kończynami operowanymi.

Wnioski: Po zabiegu rekonstrukcji ACL u części pacjentów nadal stwierdza się niestabilność operowanego stawu. Ocena funkcji oraz niestabilności stawu kolanowego subiektywną skalą Lysholma jest porównywalna z oceną wykonaną obiektywnym narzędziem badawczym – rolimetrem. U pacjentów po artroskopowej rekonstrukcji ACL występują przewlekłe zaburzenia siły mięśniowej.

Introduction

The knee is the most frequently damaged joint in the human body, with the anterior cruciate ligament (ACL) being its most frequently damaged structure, comprising 90% of all lesions [1, 2].

Normal ACL length is 38 mm (25–41 mm) and normal width is 10 mm (7–12) [3]. The ACL is believed to have different functional groups that limit the anterolateral translation of the tibia relative to the femur. They are the anteromedial (AM) bundle, which stabilizes knee flexion, and the posterolateral (PL) bundle, responsible for maintaining the stability of the joint in extension. Anterior cruciate ligament injury most often affects young, physically active people. The majority, as much as 70% of ACL injuries, are non-contact injuries and occur most frequently during a sudden change of direction or landing after a jump [4–6]. The consequence of ACL damage is instability of the knee joint. It is characterized by abnormal excessive mobility leading to subsequent episodes of subluxation and dislocation of the joint. The rupture of the ligament damages the mechanoreceptors (Paccini, Ruffini, Golgi, and free nerve endings) in the vicinity of its inserts. Disruption of the deep sensory pathways disturbs the work of the muscles controlling the joint, which intensifies the sense of instability and accelerates the processes of early degenerative changes [7, 8].

ACL tears are mainly treated by means of arthroscopic reconstruction. The most commonly used are autogenous BPTB patellar ligament grafts and grafts from flexor tendons – semitendinosus and gracilis. Reconstruction restores the mechanical stabilization of the knee joint, making the joint congruent during the examination of the anterior tibial translation. The functional stabilization of the joint is mainly influenced by the muscular system. To rebuild proper muscle strength and coordination, it is necessary to conduct comprehensive physiotherapy. An important element of this is the training of proprioception, which restores the receptors of deep sensation and better spatial control of the joint [9].

The Lachmann test is most often used to assess the stability of the knee joint in clinical practice. It demonstrates high sensitivity during manual diagnosis of anterior tibial instability [9–11]. It is used to subjectively assess knee instability following an injury, and also as a test to assess the outcome of surgery. However, its results may be challenged due to differences in the way it is implemented. The main reason for the differences is the experience of the person conducting the test [12].

Objective methods of quantifying knee stability are needed to evaluate the effectiveness of surgical treatment of the knee joint. Mechanical devices such as the KT 1000, KT 2000, and Rolimeter are the most frequently used in clinical practice [13]. The Aircast Rolimeter is designed to examine anterior and poste-

rior knee instability accurately and objectively. The device is made of stainless steel and can be sterilized if necessary. Examination by means of it is painless for the patient. The calibration needle is graduated every 2 mm, the problem seems to be the lack of standardization of the force applied to translate the examined limb. Nevertheless, the results obtained by means of it are comparable to those obtained with other arthrometers such as the KT 1000. The device allows for the quantitative examination of the tibia translation relative to the thigh in standard anterior drawer tests and Lachman. For the test to be precise and repeatable, it is important that it is always performed by the same person [14, 15].

Aim of the research

The aim of the study is to compare the knee stability of patients after arthroscopic ACL reconstruction with autograft assessed using the Rolimeter and the Lysholm scale and the impact of selected clinical factors and participation in rehabilitation on it.

Material and methods

The study included people operated on for ACL rupture in the Specialist Hospital in Rudna Mała in 2015–2018, the inclusion criteria were as follows: ACL reconstruction using an autograft with ST/GR, time from the procedure 3–5 years, and informed and voluntary consent to participate in the study. Exclusion criteria were accompanying injuries of other knee ligaments, ACL re-reconstruction, and ligament injury in the other knee joint.

According to the adopted criteria, 51 patients after ACL reconstruction using ST/GR autograft were enrolled in the study. There were 13 (25.5%) women and 38 (74.5%) men among the respondents. The average age of the respondents was 34.4 ± 7.2 years (ranging from 27 to 50 years). The mean period from reconstruction to the study was 4 years. The youngest patient was 27 years old, while the oldest was 50 years old. The studied group of patients were amateurs practicing sports. Surgical procedures were performed not earlier than 6 weeks after the knee joint injury. The criteria for qualification in the clinical trial before the surgery were as follows: no exudate, normal range of motion, efficient knee extension apparatus, 90% symmetry of quadriceps strength.

All patients received information on the course of the rehabilitation protocol after leaving the department of locomotor orthopaedics and traumatology. They underwent the recommended orthopaedic follow-ups at weeks 2 and 6, and then at 3, 6, and 12 months after the surgery. The patients underwent rehabilitation at their place of residence.

The recommended procedures from day 1 post-operatively were as follows: isometric exercises of the knee extensors and flexors, VMO electrostimulation, knee joint cooling, and high limb elevation. The stud-

ied group of patients used the knee brace for 6 weeks. Until the end of the second week, the orthosis was in full extension, at 0°. The patients used elbow crutches for 6 weeks. In the next stages of physiotherapy, the patients used the recommendations of the attending physician, continuation of exercises was carried out until 9 months after the surgery, and return to sport was possible 12 months after the surgery.

In the study, the stability of the knee joint was assessed with the Rolimeter during the Lachman test near the extension, which started with the uninvolved limb. The patient knew the test procedure, which means that he/she did not feel uncertainty and kept the muscles relaxed. The patellar end of the arthrometer was placed in the middle of the kneecap, while the tibial end was placed on the front surface of the tibia, to which it was attached with a rubber strap. The foot of the measuring needle was lowered onto the shin until it touched the tibial tuberosity. To relax the muscles during the examination, a roller was placed under the patient's knee to keep the knee joint in flexion (Figure 1). The examiner rested one hand to stabilize the plate on the patella and thereby stabilize the femur. At this time, the examiner pulled the shin forward with the other hand, performing a Lachman test near the extension. The result was read directly on a metal measuring needle, graduated every 2 mm. Three measurements were made for each limb, and the final result is the arithmetic mean [15].

The Lysholm Scale is an 8-point questionnaire describing 8 parameters: limping (5 points), weight bearing (5 points), climbing stairs (10 points), squat (5 points), instability while walking (30 points), pain (30 points), swelling (10 points), and thigh muscle wasting (5 points). The tested individual may score a maximum of 100 points, which represents the highest functional level of the limb. Its sensitivity is not stable and depends, for example, on the level of physical activity of the respondents [16].

The muscle strength test developed for the purpose of the study was made for the angular speed: 60°/s, and concentric muscle work. There was one trial of 5 repetitions for the extensors and flexors of the knee joint. Before the trial was performed, each patient received information on the method of its ex-



Figure 1. Patient prepared for examination with the Aircast Rolimeter

ecution. During each trial, patients were mobilized to engage in the physical activity performed as much as possible. The paper presents the parameter of the peak value of the maximum torque of the knee extensors and flexors in relation to body weight (peak torque/body weight) [17].

Ethical approval: The protocol of the study was accepted by the Bioethics Committee (resolution 7/2015 dated 30.01.2015)

Results

The measurement of the anterior tibial translation in the Lachman test near extension was compared using a Rolimeter on an uninvolved and operated knee. The average difference between measurements on 2 limbs was 2.09 ± 1.47 mm. There was no difference in some of the respondents in the measurement of uninvolved and operated knees, and the maximum difference was 6.5 mm. In the case of half of the respondents, the difference between 2 measurements was at least 2 mm (Table 1).

In the case of 43 (84.3%) subjects, the difference in the Lachman test near extension between the uninvolved and operated knee and Rolimeter measurement was no more than 3 mm, while in the case of 8 (15.7%) subjects it was more than 3 mm. This difference was determined as mechanical instability (Table 2).

The mean score in the Lysholm scale was 88.1 ± 12.5 points. The lowest score was 49 points and the highest was 100 points. Taking into account the 5-step

Table 1. Measurement of the uninvolved knee and operated knee with a Rolimeter – comparison

Rolimeter measurement [mm] Lachman test	Descriptive statistics						
	<i>n</i>	\bar{x}	Me	Min.	Max.	Q1	Q3
Uninvolved knee	51	4.19	4.00	2.00	7.50	2.50	6.00
Operated knee	51	5.88	6.00	2.50	10.00	4.00	8.00
Difference	51	2.09	2.00	0.00	6.50	1.00	3.00
Significance (<i>p</i>)	$Z = 4.72, p < 0.001$						

n – number of observations, \bar{x} – arithmetic mean, Me – median, Min. – minimum, Max. – maximum, Q1 – lower quartile, Q3 – upper quartile, SD – standard deviation, *Z* – result of the Wilcoxon pair-order test, *p* – level of probability.

Table 2. Interpretation of the difference in the measurement of operated and uninvolved knees with a Rolimeter

Interpretation of the difference in the Rolimeter measurement	<i>n</i>	%
Up to 3 mm	43	84.3
Over 3 mm (mechanical instability)	8	15.7
Total	51	100.0

n – number of observations, % – percentage.

Table 3. Rolimeter measurement evaluation of operated lower limb and the Lysholm scale

Variable pairs	<i>r</i>	<i>P</i> -value
Rolimeter KKO vs. Lysholm scale KKO	–0.47	< 0.001
Rolimeter KKO vs. 5-point instability Lysholm scale KKO	–0.57	< 0.001

KKO – operated lower limb, *r* – result of Spearman's rank correlation test, *p* – level of probability.

Table 4. Lysholm scale – the total and the difference in the measurement of operated and uninvolved knees with a Rolimeter

Lysholm scale [0–100]	Descriptive statistics						
	<i>n</i>	\bar{x}	Me	Min.	Max.	Q1	Q3
Up to 3 mm	43	90.00	93.00	51.00	100.00	87.00	98.00
Over 3 mm	8	77.88	82.00	49.00	100.00	67.50	87.50
Total	88.10	91.00	49.00	100.00	83.00	97.00	12.47
Significance (<i>p</i>)	<i>U</i> = 83.50, <i>p</i> = 0.020						

N – number of observations, \bar{x} – arithmetic mean, *Me* – median, *Min.* – minimum, *Max.* – maximum, *Q1* – lower quartile, *Q3* – upper quartile, *SD* – standard deviation, *U* – Mann-Whitney *U* test result, *p* – level of probability.

Table 5. Strength of flexor and extensor muscles (concentric work 60°/s peak torque/bw), comparison between limbs

Flexor strength (concentric work 60°/s peak torque/bw)	Descriptive statistics						
	<i>n</i>	\bar{x}	Me	Min.	Max.	Q1	Q3
Uninvolved lower limb	51	101.52	104.90	55.10	162.50	85.90	118.50
Operated lower limb	51	94.03	94.50	41.20	144.90	67.10	121.30
Significance (<i>p</i>)	<i>Z</i> = 1.87, <i>p</i> = 0.062						
Extensor strength (concentric work 60°/s peak torque/bw)	Descriptive statistics						
	<i>n</i>	\bar{x}	Me	Min.	Max.	Q1	Q3
Uninvolved lower limb	51	210.47	219.80	88.90	330.40	167.50	248.40
Operated lower limb	51	186.62	193.90	42.70	301.30	128.80	233.40
Significance (<i>p</i>)	<i>Z</i> = 3.49, <i>p</i> < 0.001						

n – number of observations, \bar{x} – arithmetic average, *Me* – median, *Min.* – minimum, *Max.* – maximum, *Q1* – lower quartile, *Q3* – upper quartile, *SD* – standard deviation, *Z* – result of the Wilcoxon pair-order test, *p* – level of probability.

detailed Lysholm instability assessment, no symptoms of knee instability were found in 22 (43.1%) subjects. In 20 (39.2%) subjects, instability occurred exceptionally during heavy loads, in 7 (13.7%) subjects, instability occurred exceptionally during normal daytime activity, and in 2 (3.9%) subjects it was frequent during normal daily activity. A statistically significant correlation was observed between the Rolimeter value of the operated lower limb and the Lysholm scale result. The higher the values obtained by the examined patients in the Rolimeter measurement, the lower their score on the 100-point Lysholm scale and the lower the score on the 5-point instability scale. A higher value of the Rolimeter measurement translated into a greater sensation of knee instability (Table 3).

Higher results on the Lysholm scale were obtained by the subjects from the group with anterior translation of the tibia “up to 3 mm”. The differences in the Lysholm score between subjects with an anterior tibial displacement of up to 3 mm and more than 3 mm are statistically significant (*p* = 0.020) (Table 4).

For all respondents, the flexor muscle strength assessed with the isokinetic dynamometer does not differ in the case of uninvolved and operated limbs, while the extensor strength is significantly greater in the uninvolved limb (*p* < 0.001).

To assess muscle strength, the parameter of the maximum moment of force in relation to body mass at a speed of 60°/s (peak torque/bw at 60°/s) was used. The study was carried out for the concentric work of extensors and flexors of the knee joint (con/con) (Table 5).

Table 6. Difference in the measurement of the operated limb with a Rolimeter and the type of rehabilitation

Type of rehabilitation	Descriptive statistics						
	<i>n</i>	\bar{x}	Me	Min.	Max.	Q1	Q3
Physical + individual	42	1.99	2.00	0.00	5.00	1.00	3.00
Physical therapy	9	3.08	2.50	2.00	6.50	2.00	3.00
Significance (<i>p</i>)	$U = 81.50, p = 0.169$						

n – number of observations, \bar{x} – arithmetic average, Me – median, Min. – minimum, Max. – maximum, Q1 – lower quartile, Q3 – upper quartile, SD – standard deviation, *U* – Mann-Whitney *U* test result, *p* – level of probability.

People who received only physical therapy obtained a greater value in the Rolimeter measurement than people who received both physical therapy and individual therapy. In the case of people who received only physical therapy, the mean value of the measurement was 3.08 ± 1.74 mm, and in the case of people who received physical therapy together with individual therapy, the mean value of the measurement was 1.99 ± 1.39 mm (Table 6).

Discussion

Instability of the knee joint affects both young people practicing sports as well as elderly people with degenerative changes in the knee joint. The stability of the knee joint is ensured by the cooperating systems of passive stabilizers (ligaments) and active (muscles). The cooperation of the ligamentous and muscular systems is coordinated by the central nervous system (CNS) by transmitting information about the position of the joint in space from the proprioceptors to the brain and then to the effectors/muscles. Factors influencing the occurrence of instability of the knee joint are mainly ligament damage, degenerative changes in the knee joint, and muscle weakness as a result of injury or chronic diseases [18, 19].

Mechanical instability is the main symptom of ACL damage. The main purpose of ligament reconstruction is to restore the proper biomechanics of the joint. Its correct congruency affects the ability to function in everyday life and during sports activities. Ardern *et al.* [20] note that with good functional results and high subjective assessment of the joint in the examined patients, as many as 56% of them did not return to their pre-injury activity. A frequent reason for decreased physical activity in patients after ACL ligament reconstruction is the fear of repeated joint injury [20]. The feeling of an unstable knee also influences the decision to give up sports. In the pathophysiology of knee joint injuries, there are functional and mechanical instabilities. Functional instabilities arise as a result of disturbed proprioception; professional rehabilitation aims to restore it. On the other hand, mechanical instabilities result from damage to the ligament structure [21].

A Aircast Rolimeter Arthrometer was used to assess the clinical instability of the knee joint in our study. In the examined group of patients, 15% demonstrated

knee instability exceeding 3 mm compared to the uninvolved limb. It is a quantity denoting ligament insufficiency as described by the authors [13, 22, 23]. Bach *et al.* described the results of patellar tendon autografts 2 years after the procedure, and showed that 5% of patients had a difference of more than 3 mm between their knees [24]. Indelli *et al.* assessed the Achilles tendon allografts in the period from 3 to 5 years after the procedure and obtained the mean difference between the uninvolved and operated limb at the level of 2.3 mm, and in 66% of patients a difference of less than 2 mm [25]. Biau *et al.* state in their meta-analysis that the normal function of the knee is restored only in 37% of patients undergoing ACL reconstruction [26]. Instability of the knee joints is also frequent, with 31.8% of patients demonstrating a positive Lachman test result and 21.7% of patients having a positive pivot shift test result [27]. It is difficult to unequivocally determine the cause of the knee instability after ACL reconstruction. It is known that damage to the ligament also causes damage to the proprioceptors. Proprioception disorders may therefore be the cause of increased joint laxity as well as its consequence. Research indicates that chronic neuromuscular deficits after ACL damage are the result of insufficient neuronal adaptation in the central nervous system (CNS). Permanent reorganization of the CNS caused by changes in synaptic connections between neurons in response to a limited amount of internal and external stimuli from proprioceptors affects persistent disturbances in motor reactions [28].

Our study presents the relationship between the results of the Rolimeter measurement and the results of the Lysholm scale. The better the Lysholm score, the less the anterior tibia translation. According to Kharea [29], this relationship is related to the length of the rehabilitation process and acts in such a way that the longer the rehabilitation is conducted, the better the Lysholm score and the less the anterior translation of the tibia. Our study revealed a certain tendency between the results of the knee joint stability and the type of rehabilitation performed. People who benefited from physical therapy alone obtained an average result in the Rolimeter study of 3.08 ± 1.74 mm, and in the case of people who received physical therapy together with individual therapy, the mean value was 1.99 ± 1 mm. The observed difference in the results was not statistically significant ($p = 0.169$).

In the examined group of patients, the deficit in strength of the quadriceps muscle of the thigh in relation to the uninvolved limb was observed. The weakening of the strength of the quadriceps muscle in patients after ACL reconstruction is common despite the rehabilitation strategy aimed at its strengthening. Chronic weakness of the knee extensors may be caused by persistent abnormal gait pattern, impaired deep sensation, or atherogenic muscle inhibition (AMI) [30]. Atherogenic muscle inhibition is a continuous reflex response to damaged intra-articular structures that affect periarticular muscles. In patients with injuries of the knee joint, sensory information from articular mechanoreceptors is disturbed, which results in the weakening of the efferent quadriceps muscle stimulation. Thus, the volume of motor units available for the voluntary recruitment of muscle fibres is reduced [31, 32]. An important consequence of AMI is the inability to fully activate the quadriceps due to the limited availability of the quadriceps motor units. This abnormality plays a major role in post-traumatic weakness of the quadriceps and may indirectly contribute to the alteration of gait patterns frequently observed in people with ACL injuries [33]. The weakening of the strength of the quadriceps muscle is manifested, for example, by the lack of proper control of tibial translation during gait. Lack of dynamic stabilization increases the risk of damage to intra-articular structures as a result of reduced depreciation and dissipating loads on the knee joint in the initial phases of the support [32, 33]. During increased effort, the weakened quadriceps muscle may be more fatigued, which may result in pathological movements in the joint, perceived as a feeling of joint instability [34].

Stability assessment is the basis for assessing the function of the knee after ACL reconstruction. Proper mechanical and functional stabilization guarantees the ability to freely perform the most complex motor activities. The Rolimeter is an accurate, simple, and economical device that provides a quantitative assessment of the anterior tibial displacement [14]. The results of many authors, including Ganko *et al.* [15], indicate that the Rolimeter is a reliable device for the objective assessment of knee laxity. The results obtained in the study correlate with the results of much more expensive and therefore less available devices such as the KT-1000 arthrometer [15].

Conflict of interest

The authors declare no conflict of interest.

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