



The influence of functional shortening of hamstring muscles and rectus femoris muscle on proprioception of knee joint in patients after ACL rupture

Wpływ funkcjonalnego skrócenia mięśni kulszowo-goleniowych i prostego uda na kinestezję stawu kolanowego u pacjentów z zerwaniem ACL

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ABSTRACT

INTRODUCTION: The aim of this study is to demonstrate the relationship between functional shortening of the rectus femoris muscle, hamstring muscle and knee proprioception in patients after anterior cruciate ligament [ACL] rupture.

MATERIAL AND METHODS: A group of 35 men with ACL rupture (without ACL reconstruction), aged 18 to 43 years (28 ± 7.4 years) was enrolled in the study. Firstly, the functional shortening of above mentioned muscles was evaluated in both healthy and injured lower limbs. Knee joint proprioception was assessed using a BTE Primus RS by examining the angular deviation from the center of the kinetic range in the knee joint with and without visual inspection.

RESULTS: A statistically significant positive correlation was found between the functional shortening of the hamstrings and the proprioception of the flexion motion assessed under conditions without visual inspection. In addition, a statistically significant negative correlation was found between the functional shortening of the rectus femoris muscle of the injured lower limb and proprioception of the knee flexion movement assessed under conditions without visual inspection.

CONCLUSIONS: A deficit of knee proprioception correlates with the functional shortening of the thigh muscles. Patients with functional shortening of the rectus femoris have better knee proprioception. Patients with functional shortening of hamstrings have worse knee proprioception.

KEY WORDS

proprioception, functional stability, sensorimotor system, passive stiffness, neuromuscular control

Received: 22.12.2017

Revised: 16.03.2018

Accepted: 22.03.2018

Published online: 08.05.2018

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**STRESZCZENIE**

WSTĘP: Celem badania jest wykazanie związku między skróceniem czynnościowym mięśnia prostego uda i mięśni kulszowo-goleniowych a kinestezją stawu kolanowego u pacjentów po zerwaniu więzadła krzyżowego przedniego [ACL].

MATERIAŁ I METODY: Badaniem objęto grupę 35 mężczyzn z zerwaniem ACL (bez rekonstrukcji) w wieku od 18 do 43 lat ($28 \pm 7,4$ roku). Funkcjonalne skrócenie wyżej wymienionych mięśni oceniano zarówno na zdrowej, jak i kontuzjowanej nodze. Kinestezję stawu kolanowego oceniano za pomocą aparatu BTE Primus RS, badając odchylenie kątowe od środka zakresu ruchu w stawie kolanowym z i bez kontroli wzroku.

WYNIKI: Stwierdzono statystycznie istotną dodatnią korelację między funkcjonalnym skróceniem mięśni kulszowo-goleniowych a kinestezją dla ruchu zgięcia ocenianego w warunkach bez kontroli wzroku. Ponadto stwierdzono istotną statystycznie ujemną korelację między funkcjonalnym skróceniem mięśnia prostego uda nogi uszkodzonej a kinestezją ruchu zgięcia kolana ocenianego w warunkach bez kontroli wzroku.

WNIOSKI: Deficyt propriocepcji kolana koreluje z funkcjonalnym skróceniem mięśni uda. Pacjenci z funkcjonalnym skróceniem mięśnia prostego uda mają lepszą kinestezję stawu kolanowego, natomiast u pacjentów z funkcjonalnym skróceniem ścięgien podkolanowych stwierdzono gorszą kinestezję stawu kolanowego.

KEY WORDS

propriocepcja, system sensomotoryczny, sztywność pasywna, kontrola nerwowo-mięśniowa, czynnościowa stabilność

ARTICLE

One of the most common sport injuries is a lesion of the anterior cruciate ligament (ACL). The consequence of ACL rupture is not only knee instability caused by the loss of mechanical function (anterior translation, extension and hyperextension), but also the loss of sensory information that affects the neuromuscular control mechanisms. Lephart's study [1] showed a significant decrease in quadriceps, hamstring and gastrocnemius muscle response in a knee with an ACL lesion compared to a healthy lower limb. In the case of ACL damage, functional adaptation involves increased hamstring muscle activity, which, by its increased stiffness, protects the frontal translation. Adaptive changes also engage the quadriceps, which is an antagonist to the function of the anterior cruciate ligament. Therefore, in the case of ACL damage, reflex inhibition of the quadriceps occurs [2]. This phenomenon is understood to mean a situation in which sensory stimulation hinders muscle activity. Reduced muscle stimulation through abnormal afferent information obtained from a damaged joint results in muscle weakness and muscle atrophy as a consequence [2]. In this paper we focus on the relationship between functional shortening and the proprioception deficit as measured by proprioception testing in the knee joint in patients after ACL injury.

MATERIALS AND METHODS**Study group**

The study was conducted in a group of 35 men aged 18 to 43 years (28 ± 7.4 years). The research group consisted of ACL injury (confirmed by MRI and by a doctor with orthopedic and surgical specialization), treated conservatively (without ACL reconstruction), with no other joint injuries within 3 years. The mean time after the rupture incident was 38 weeks (± 27 weeks). Another inclusion criterion was the possibility of passive and active flexion motion in the knee joints above 90 degrees.

METHODS

All the participants were subjected to the following tests: firstly, the functional lengths of the hamstring muscles and rectus femoris muscle were evaluated both passively (classically) and ballistically [3,4,5]. In the passive method the researcher performed the movement without active participation of the participant, whereas in the ballistic method the task of the participant was to perform the movement in the opposite direction to the function of the analyzed muscle



group. In both methods, the participant was asked to focus on his feelings during the tests. The test was stopped at the moment in which the subject reported a slight feeling of tissue resistance or a distinct traction sensation in the examined muscle group. During the measurement, no one reported pain in the knee. Each measurement was performed three times. The average value of three measurements was taken for further analysis. The following groups of muscles were examined:

Hamstring muscles: the patient was lying in the supine position and his lower limb was in the triple-bend position with a stabilized pelvis. The hip joint was set at the angle of 90° on the tested side. In the passive measurement, the "lacking-angle" test was performed, where the patient made a passive extension of the knee joint till elastic resistance or strong discomfort. In the ballistic measurement, the patient extended the knee joint on his own, completing above-mentioned conditions of the test. In both methods, the inclinometer was placed to the bone below the tibial tuberosity (zero was set in the vertical position, consequently the "lacking-angle" was tested – the obtained value was a lacking variance to achieve 0°).

Rectus femoris muscle. The patient was lying in the prone position and the lower limb which was not examined was placed off of the couch, perpendicular to surface with knee flexion and the whole foot placed on the floor. The pelvis was stabilized by the examiner. In the passive measurement the examiner flexed the knee passively till strong, elastic resistance or till the patient expressed discomfort. In the ballistic measurement, the patient flexed the knee himself till he felt elastic resistance of the muscles. The inclinometer was situated each time on the tibia below the tibial tuberosity (zero was set in the vertical position)

The knee proprioception was evaluated in BTE Primus RS, where its angular measurement function was performed in the sagittal plane of the healthy and injured knee and the possibility of stopping the dynamometer arm by the participant at any joint angle during movement performance [6]. The test on healthy and injured limbs was performed both with open and closed eyes. No movement speed was imposed and no additional resistance was applied besides the tested lower limb mass and constant mass of the dynamometer arm (1200 g). The subjects were tested in the seated position. The shin was placed between the lever arm covers of the dynamometer so that they were above the lateral ankle, allowing free movement of extension and flexion of the knee throughout the specified range. The rotation axis of the dynamometer was set according to the axis of rotation of the knee joint. In the proximal part, the tested limb was stabilized by a transverse belt at 1/3 of the distal part of the thigh. The pelvis and torso were stabilized. The position is shown in Figure 1.



Fig. 1. Subject during extension test for proprioception in knee joint – author's own material.

Ryc. 1. Pacjent podczas wyprostnego testu na propriocepcję w stawie kolanowym – materiały własne.

The task was to perform extension of the knee joint in the range 0–90° (where zero was in the horizontal position) and then the participant was asked to repeat the stretch with the difference that he had to press a button to stop the possibility of further movement when he was in the "middle" of this range. This mechanism allowed the tester to observe the actual angular setting. This procedure was repeated twice. The subject was then tested in the same way for bending movement, starting with the extended knee. Subsequently, tests without visual inspection (closed eyes) were repeated. Better test results, closer to the center of the range of motion, were entered in the following equation, which evaluated proprioception based on the sample error (the lower the value obtained from the equation, the better the test, where zero is the ideal outcome – the center of the range):

$$Z = [(Y - X) / Y] \times 100$$

Y – standard (50% of the sample value – half of the range)

X – real test value

Z – sample error value (absolute value)

Statistical analysis

The results of the study were statistically evaluated using STATISTICA PL StatSoft (version 10). Pearson's correlation coefficient was calculated as well as the elasticity of the muscle groups and the values of possible proprioception differentiation in the knee joint of the injured and healthy limbs. The critical significance level of the differences was assumed to be $p < 0.05$.

**RESULTS**

The statistical analysis revealed a positive correlation between the functional shortening of the hamstring muscles of the injured lower limb and the proprioception of the flexion assessed under conditions without visual inspection (tested both passively and ballistically). The other results were not statistically significant. The data is presented in Table I.

A negative statistically significant correlation was noted between the functional shortening of the rectus femoris muscle – tested passively and ballistically – and the proprioception of knee flexion assessed under conditions without visual inspection (respectively $p = 0.043$ and $p = 0.007$). For the remaining analyses, there were no statistically significant correlations between the analyzed results. The results are shown in Table II.

Table I. Correlation coefficient (r) between knee proprioception, and measurement of functional length of hamstring muscles

Tabela I. Współczynnik korelacji liniowej Pearson'a (r) pomiędzy propriocepcją stawu kolanowego, a pomiarem długości funkcjonalnej mięśni kulszowo-goleniowych (KG)

Test	Passive measurement of functional length of hamstring muscles		Ballistic measurement of functional length of hamstring muscles	
	healthy lower limb	Injured lower limb	healthy lower limb	Injured lower limb
Knee extension – eyes opened	$r = -0.1492$ $p = 0.627$	$r = 0.1036$ $p = 0.457$	$r = -0.1057$ $p = 0.426$	$r = 0.2464$ $p = 0.368$
Knee extension – eyes opened	$r = -0.1474$ $p = 0.265$	$r = 0.0252$ $p = 0.097$	$r = -0.1597$ $p = 0.214$	$r = -0.1532$ $p = 0.869$
Knee flexion – eyes opened	$r = 0.0368$ $p = 0.84$	$r = 0.3268$ $p = 0.169$	$r = 0.4269$ $p = 0.086$	$r = 0.0428$ $p = 0.966$
Knee flexion – eyes closed	$r = 0.1576$ $p = 0.639$	$r = 0.3576^*$ $p = 0.021$	$r = -0.1568$ $p = 0.74$	$r = 0.4567^*$ $p = 0.038$

* statistically significant correlations, $p < 0.05$

* korelacje istotne statystycznie, $p < 0,05$.

Table II. Correlation coefficient (r) between knee proprioception, and measurement of functional length of rectus femoris muscles

Tabela II. Współczynnik korelacji liniowej Pearson'a (r) pomiędzy propriocepcją stawu kolanowego a pomiarem długości funkcjonalnej mięśnia prostego uda

Test	Passive measurement of passive inflexibility		Measurement of ballistic functional length of muscle	
	healthy lower limb	Injured lower limb	healthy lower limb	Injured lower limb
Knee extension – eyes opened	$r = -0.186$ $p = 0.523$	$r = -0.4356$ $p = 0.179$	$r = -0.055$ $p = 0.724$	$r = -0.179$ $p = 0.357$
Knee extension – eyes closed	$r = 0.190$ $p = 0.842$	$r = -0.369$ $p = 0.428$	$r = -0.2603$ $p = 0.527$	$r = -0.2467$ $p = 0.628$
Knee flexion – eyes opened	$r = -0.2457$ $p = 0.472$	$r = 0.3176$ $p = 0.326$	$r = -0.5321$ $p = 0.156$	$r = 0.4721$ $p = 0.092$
Knee flexion – eyes closed.	$r = -0.3745$ $p = 0.102$	$r = -0.4284^*$ $p = 0.043$	$r = 0.6896$ $p = 0.084$	$r = -0.5629^*$ $p = 0.007$

* statistically significant correlations

* korelacje istotne statystycznie

DISCUSSION

ACL damage involves many disorders of normal functioning of the knee [7]. The absence of this important articular receptor increases the passive stiffness of the muscles surrounding the joint [8,9]. Several studies have been conducted to evaluate the effect of ACL on proprioception of the knee joint. Lee et al. [10] concluded that in patients with ACL rupture, the

threshold to detect passive motion (TDPM) strongly correlated with the dynamic stabilization in one lower limb stance activity. In Lee's study TDPM was measured in the following way: the participants were asked to "concentrate on the knee" and respond when they felt any sensation of movement or change in position by flipping a switch. The knee was being rotated at an angular velocity of $0.5^\circ/s$. Hence, it was quite a different procedure than the one applied in the present study because there was rotational movement



tested there and the threshold for the sensation of motion was checked. In turn in the study described in the present article, flexion and extension movements were tested, and the tested parameter was the ability to set the joint in the given position. By contrast, in the above mentioned study, dynamic single limb stance balance does not show a significant correlation with knee laxity or the strength of the knee muscles. Unfortunately, the study was conducted only among 10 individuals, therefore strong conclusions cannot be drawn from it. Other studies performed on patients with ACL injury indicate a proprioception disorder of the injured joint [11]. In the study presented in this article, a positive correlation was found between functional shortening of the hamstring muscles with joint movement sense for flexion motion in the knee joint on the injured side. These results were statistically significant only in the case of the closed-eye tests (proprioception tests), but only for flexion motion. Similar ACL-related outcomes have been reported by other authors [12,13].

If we assume that an increase in functional shortening of the lateral muscles of the thigh is a compensatory mechanism for ACL, inhibiting frontal translation in the joint [14], it is connected with worse proprioception. Going further we can ask: is proper rehabilitation, optimizing the disbalance between the knee flexors and extensors able to improve this dysfunction? Larsen et al. conducted this type of study [15]. No changes in knee joint proprioception were observed immediately after passive hamstring stretching, but this study was performed in healthy patients, so the efficacy of this type of therapy in ACL trauma patients continues to be questioned. Perhaps to remedy this problem, it is necessary to reconstruct this ligament, to provide correct mechanics to the joint, and to provide better conditions for the muscles? The answer to this

question can be found in the Lephart study, which concludes that in most patients with ACL abnormalities, proprioceptive deficits leading to functional instability continue to persist but to a smaller degree after reconstruction [1]. Therefore, it means that ACL reconstruction does not guarantee full recovery. A separate issue is the impact of time that has elapsed since the injury. Lee et al [10] observed that patients with chronic ACL rupture achieved better results in stability tests than patients who were less than 3 months after their injury.

Another correlation was statistically significant: the smaller the functional shortening of the rectus femoris muscle, the worse the deep knee sensation was. As in the case of the previous muscle group, the results for these were statistically significant only in the case of the closed-eye tests. Based on the above results, it can be assumed that in patients with ACL abnormalities, working on functional muscle length may be important to improve proprioception but we do not know to what extent. The fact that the results were statistically significant only for flexion motion is also interesting. Further studies will be necessary to test the effect of different therapies on the tested parameters, with a comparison of the results before and after the treatment.

CONCLUSIONS

A deficit of knee proprioception correlates with functional shortening of the rectus femoris and hamstring muscles. Patients with functional shortening of the rectus femoris have better knee proprioception. Patients with functional shortening of the hamstrings have worse knee proprioception.

Author's contribution

Study design – M. Szlęzak
Data collection – W. Likus, M. Krupa
Statistical analysis – M. Szlęzak, W. Likus
Manuscript preparation – K. Ficek, B. Matuszyny
Literature research – B. Matuszyny
Manuscript preparation – K. Ficek

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