KNEE JOINT POSITION SENSE IN PHYSICALLY ACTIVE PATIENTS AFTER ACL RECONSTRUCTION

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Abstract. The term “proprioception” is defined as the conduction of sensory information deriving from proprioceptors that have an impact on conscious sensations, posture and trans-segmental sense. An ACL injury may lead to functional knee joint instability. According to research, this may result in impaired movement sensation and joint position.

The purpose of this study was to evaluate the joint position sense (JPS) in patients before arthroscopic ACL reconstruction and 5 months after the surgery. The examinations were conducted in a group of twelve specifically selected male patients. The examination procedure consisted of JPS measurement in both lower limbs (the operated and the healthy one) during active extension in a range of angles: 30, 45, 60°. The level of significance was: $p < 0.05$.

The analysis of variance performed for repeated measurements (ANOVA) did not indicate any statistically significant differences of JPS in comparisons made between the operated and the healthy limb. Statistical values for the absolute, relative, and variable errors were $p = 0.7684$, $p = 0.1546$, $p = 0.5694$ respectively. The obtained results do not indicate any limitation of proprioception in patients with ACL injury before the intervention or half a year later.

Key words: knee, anterior cruciate ligament, joint position sense, reconstruction

Introduction

There are various ways in which the sensory information may reach the Central Nervous System. It is passed through the specific group of receptors called proprioceptors. The afferent information, derived from proprioceptors which are deployed in proprioceptive spots, has an influence on: conscious sensations (muscular sense), body posture (balance), and trans-segmental sense (joint stability) (Lephart et al. 1997, 2000). The interpretation of these signals occurs in the central nervous system. Their activity may result from pressure change, or contraction/extension of tissue that takes place during a change of joint position. Proprioception integrates the functions of static (capsular

– ligament complex) and dynamic (group of muscles actively connected with a certain joint) joint stabilizers and protects the joints against injuries during activity. Each dysfunction of a ligament – capsular apparatus that perturbs the level of neuromuscular control, correspondingly perturbs the static and dynamic mechanisms' synchronization and leads to joint dysfunction as well as to further damage and degeneration in subsequent stages. In recent years, extensive research has been conducted, dedicated to the sensory role of the ACL and to the analysis of how its damage influences knee joint function. According to Fremerey et al. (2000), the mechanoreceptors responsible for bathyesthesia comprise from 1–2% of ACL capacity. In majority cases, the injury is the result of rotation forces acting on a knee joint fixed in the valgus position or hyperextension without contact with other people. This mechanism relates very often to athletes aged between 15 and 25 years (Van Grinsven et al. 2010). Damage of the passive stabilizer – which is the ligament, is often the consequence of a lack of dynamic stabilizer function (by dynamic stabilizers we mean muscles). Lacks of coordinated motion and/or incorrectly conducted motor training in competitive sports are often the reasons for knee joint disorders. Additionally, lacking a competent ACL may expose the joint to re – injury with the possibility of further articular meniscus or articular cartilage damage that may lead to degenerative changes. It concerns not only professional athletes but also athletes at all levels (Lephart et al. 1997, 2000).

ACL reconstructions are performed in order to avoid the abovementioned changes. ACL reconstruction is the kind of surgery that requires the recreation of a ligament in its anatomical position or as close as possible to anatomical position. In order to perform ACL reconstruction, the grafts that are used most frequently are: 1/3 medial patellar ligament (PBTB – bone – patellar tendon – bone graft), semitendinosus tendon or two tendons: of semitendinosus muscle or of gracilis muscle – if the dimensions of one tendon are insufficient to perform the quadruple – bundle graft. The graft originates either from the patient's tissues (autogenous graft) or from a donor (allogenic graft – allograft) (Nakamura et al. 2002).

Many researchers are trying to find newer and newer methods and explain proprioception's devices, in order to identify its "defects" and, thereby make possible the early prevention of joint instability and in consequence – its injury (Fremerey et al. 2000). JPS examination allows us to evaluate the proprioception of a knee joint in a quantitative manner in both active and passive motion, presented in angular degrees. Research about the evaluation of JPS and proprioception disorders in ACL injury, as described in the literature, provides contradictory results. In their research, (Fremerey et al. 2000) and (Fischer and Jensen 2000) presented a significant disability of proprioception in patients with ACL injury. Barrett et al. (1991) and Barrack et al. (1989) also presented definite reduction of JPS ability in the knee with an injured ligament. According to this research, ACL injury – where ACL is also the mechanical (static) knee joint stabilizer, causes the ACL proprioceptor dysfunction and sensory deficits. They explain that with the reduction in number of proprioceptors, muscle function changesand consequently, joint instability results (Johansson et al. 1991; Rehm et al. 1998; Reider et al. 2003).

As observed in the research, injured joint signal disorder may also cause the abnormities in movement perception and position of analogical joint in the healthy limb (O'Connell et al. 1998). Good et al. (1999) demonstrated antithetical results suggesting that ACL injury does not cause any change in proprioception. Co and Cannon (1993), Beard et al. (1994), Harteret al. (1992) and Skinner and Barrack (1991) in their research were also unable to find statistically significant differences between a healthy limb and the one with anterior knee instability among healthy control subjects. MacDonald et al. (1996), according to their conclusions, also presented JPS results which were difficult to interpret.

Objective

The objective of this study was to evaluate knee joint position sense in patients before the arthroscopic ACL reconstruction and a period of 5 months after the intervention. It was also meant to verify the influence of ACL reconstruction with autogenous semitendinosus muscle tendon and gracilis muscle tendon graft on proprioceptive knee joint position sense.

Methods

The research project was agreed to by the Bioethical Committee of Scientific Research at Academy of Physical Education (resolution no. 6/12 of June 1st 2011). The research was carried out in a group of 12 specifically selected men (mean age: 26.5 ±6.5 years, mean weight: 82.8 ±4.8 kg, mean height: 179.3 ±4.5 cm). All of the patients regularly practiced amateur sports before the injury and had their ACL injured during a sporting activity. All the examined were diagnosed with ACL injury based on their medical history and additional imaging examinations. All of them had been previously qualified for surgical treatment due to unilateral, post–traumatic anterior knee joint instability. ACL injury concerned only one of the limbs. The healthy limb was treated as internal control. The arthroscopic ACL reconstruction was conducted in each case by keeping the ligament's original stumps and using autogenous semitendinosus and gracilis muscle tendons. Patients with articular cartilage damage of 3rd and 4th grade and those with the complete meniscus removal were excluded from the tests. The patients recovered according to individualized rehabilitation programs both before the surgery, and five months after it. The complex physiotherapy included: physical therapy, proprioceptive training, and functional training. All the subjects had to present painless range of motion to allow for measurement in accordance with the elaborated method. The patients were informed of the objective, character and manner of conducting the examination and they expressed their written consent to participate in it. Pilot measurements were performed prior to the tests in order to acquaint the patient with their method and to make him accustomed to the given commands. Before each test, the device's calibration was tested and a warm-up on the stationary bicycle was performed. The examination procedure consisted of active, intentional reproduction of knee joint flexion in the following angular positions: 30, 45, 60°. The decision was made to carry out the test of active joint reproduction to give us more afferent information as compared with a JPS passive test (Olsson et al. 2004), and as evidenced by the research of Beynnon et al. (2000) such a test yields the largest repeatability and sensitivity of the test. For the purpose of this study, the absolute mean error (the average error in the tree trials ignoring the direction of the error), relative error (the average of errors in the three trials taking into account the direction of the error), and variable error (the standard deviation of the three relative error measurements) were calculated (Olsson et al. 2004).

The measurements of active reproduction of knee joint position were conducted using a functional evaluation device, equipped with electronic goniometer – Baltimore Therapeutic Equipment (BTE) PRIMUS RS. The subject was placed on a chair, with his head and his back on a specially profiled back and head rest, so that his hip joints were at an 80° flexed position. Both upper limbs were positioned along the trunk with their elbows bent and their hands placed on the thighs. The seat depth was set so that the popliteal fossa were 3 cm from the edge of the seat. The lower legs were hanging with the knee joint positioned at 90°. The goniometer axis of rotation was set exactly with the pivot axis of the knee joint, placed in the frontal plane and extended horizontally through beyond, over the femoral condyles. The adapter, attached to the head of the goniometer stabilized the lower leg using a special sponge-filled belt to bridge the skin sensation. The subject was blindfolded in order to eliminate visual information. The commands were given right before the test. The patient was fastened in place with chest, hip and thigh belts, to stabilize his position. Before the measurements, the individual range of motion had been set in the ranges from 0° – full knee joint extension to 90° knee joint flexion. Afterwards, the examiner passively set the target angle in the patient's knee joint. Once the target angle had been achieved, the movement was held for 5 sec. In that time, the subject was asked to remember the given angular settings and thereafter to repeat them three times. The tests were repeated three times for each angle. The rest between all the attempts lasted 10 seconds. There was the pause of 10 seconds between placement and the subject's effort to repeat the angle and the examiner returned the knee to 90° flexion before the subject attempted to repeat it. The examinations were carried out before the surgery and then every 4 weeks for the following six months.

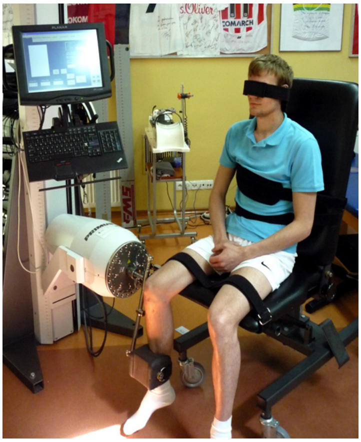

Figure 1. Subject during the JPS trial

Statistical analysis

The JPS examination result (for each angular setting: 30°,45°,60°) was presented by the average value obtained from three measurements for each of the given angular settings. The means of each, obtained in that way, were compared by the analysis of variance for the repeated measurements ANOVA for every dependent variable: JPS absolute error, JPS relative error, and JPS variable error, which characterize the accuracy and precision of measurement (Brindle et al. 2010; Olsson et al 2004). The obtained results were elaborated based on the commonly used statistical analysis method, by means of STATISTICA software package, version 10 (StatSoft, Inc. 2011). Quantitative marks were described by using the arithmetic average, standard deviation (SD), skewness and kurtosis. The statistically significant differences between the variables for both limbs were examined. With the purpose of determining the statistical differences, significance level of the post–hoc analysis was carried out. Bonferroni multiple comparison was chosen to carry out the analysis. The significance level in all the statistical tests was $p < 0.05$.

Results

Analysis of variance for the repeated measurements of the variable: absolute, relative, and variable error 3 × 3 ANOVA (angle 60°/ 45°/ 30°) did not demonstrate a statistically significant JPS variability in either of the limbs, either before or five months after the arthroscopic ACL reconstruction. Post-hoc analysis (Bonferroni test) did not reveal any significant differences between the examined angular positions: (60, 45, and 30°). The biggest difference of the active reproduction of knee joint position was noticed in the variable error scores for the angle of 45°.

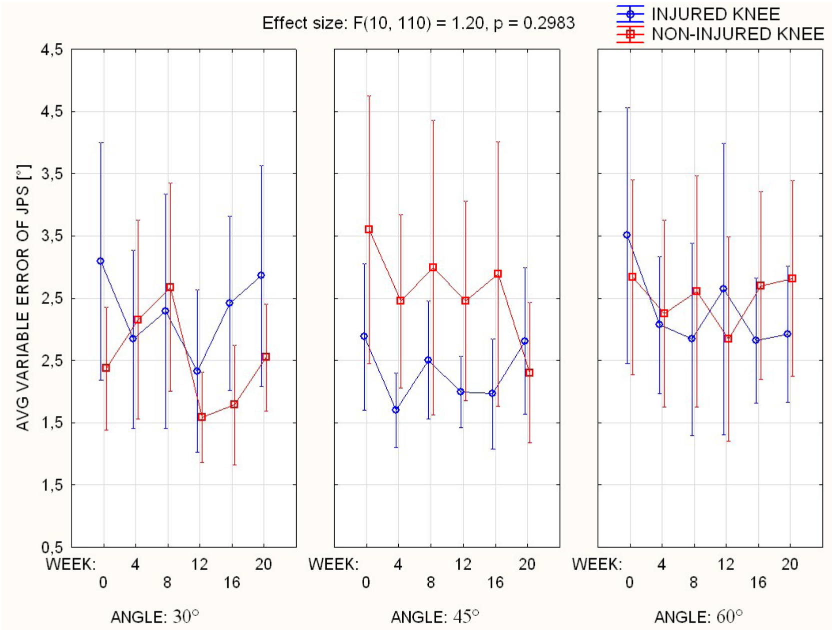

Figure 2. Differences between injured ACL and non-injured ACL knee in average variable error of JPS in 4th, 8th, 12th, 16th, and 20th week

Discussion

Research concerning JPS evaluation of the knee and proprioception disorders in patients with ACL injury has contradictory results.

Fremerey et al. (2000) in their research of knee joint proprioception were trying to evaluate the batyesthesia in the pre – and post – operative period. Six months after the arthroscopic reconstruction, the complete recovery of proprioceptive sense was found only in the ranges of full extension and flexion. Whereas in the intermediate range of movement, the proprioceptive sense improvement was negligible. Nonetheless, similar results to those of the intermediate range of movement were noticed in healthy patients of the control group. Al-Othman (2004) in his studies, demonstrated full proprioceptive sense recovery in patients after ACL reconstruction, whereas Bonfim et al. (2003) did not find any improvement of the knee joint proprioceptive function after ACL reconstruction in comparison with the control group. Other authors (Carter et al. 1997; MacDonald et al. 1996) describe a lack of significant differences in knee JPS examination, which is explained by the muscle activation (neuromuscular connections) in the stage of reproducing a given joint position, forcing the signal passage in an open feedback loop. As they claim, the muscle involvement in the process of reproducing a joint position limits the possibility of isolated evaluation of the impact that the ligament damage may have on JPS. On the other hand, the same muscle involvement lets us evaluate the impact that the damage has on the functional, dynamic joint stabilization via JPS test in the active movement with the joint's natural loads.

In our study, we were unable to find any statistically significant value differences of active error score for knee joint position reproduction in any of the tested positions.

Conclusions

The results of the conducted examination did not demonstrate any significant JPS diversity between individual limbs. JPS evaluation did not allow the limb with ACL injury to be distinguished from the healthy one in the tested angular flexion range (60, 45, 30°). We can conclude that ACL reconstruction with autogenous semitendinosus and gracilis muscle tendons, has less impact on proprioceptive JPS restitution in the following angular range (60, 45 and 30°). It was noticed in the analysis of JPS test results that depending on the final effect – the systematic sport activity, performed by the examined patients before the surgery, might possibly influence the final result. We may conclude that the physical activity effects the improvement of the proprioceptive sense mechanisms, the result of which may be the recovery of conscious "joint sense" and dynamic joint stabilization achievement. In our studies, we were restricted by a small number of patients and the fact that only the JPS had been evaluated, among a wide range of other scientific methods of knee joint proprioception examination e.g. evaluation of differentiation for given level of muscular strength, active reproduction of the joint position for the opposite limb.

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