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ORIGINAL RESEARCH

Functional status in non-elite football players 6 months after anterior cruciate ligament reconstruction

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Abstract

Background: Objective criteria to accurately evaluate the ability of a patient to make a risk-free return to their previous level of activity after anterior cruciate ligament reconstruction (ACLR) and to progress through stages of the rehabilitation process are still widely discussed. **Objective:** The goal of the study was to investigate the functional status of non-elite football players 6 months after ACLR based on the Functional Movement Screen test (FMS) and side-to-side differences of isokinetic quadriceps and hamstring peak torque between the operated (OP) and non-operated (NOP) extremities. **Methods:** A total of 35 football players (male:female ratio 31:4, mean age 24.7 ± 2.8 years) who had undergone primary and isolated ACLR were assessed 6 months (mean 6.1 ± 2.6) after surgery. Functional performance evaluation included the FMS test and isokinetic quadriceps/hamstring peak torque values examined using the Biodex Testing System at angular velocities of 60 deg/s and 180 deg/s. In addition, side-to-side differences for flexion and extension at both angular velocities were calculated by the limb symmetry index. **Results:** In the functional assessment, the overall score of the FMS test was 15.34 ± 2.60. Moreover, inter-extremity differences in all isokinetic strength tests were statistically significant. Isokinetic strength peak torques of quadriceps and hamstring of NOP were significantly higher than those of OP at both angular velocities ($p < .001$). The limb symmetry index results for recorded peak torques at 60 deg/s were 75% in extension and 88% in flexion and at 180 deg/s were 79% in extension and 86% in flexion. **Conclusion:** The presented data indicate explicit inter-extremity muscles strength differences and disturbances in global movement patterns after ACLR. Delayed recovery of muscle strength and disparities between the OP and NOP limbs 6 months after ACLR may undermine the patient's readiness to return to preoperative activity.

Keywords: anterior cruciate ligament reconstruction, isokinetic strength, Functional Movement Screen, functional assessment

Introduction

Among football players, anterior cruciate ligament (ACL) injury occurs as one of the most common knee traumas (Crossley et al., 2020; Myer et al., 2013; van Melick et al., 2016; Waldén et al., 2011). Studies show that 75–93% of soccer-related injury cases concern the lower extremities (Dvorak et al., 2011) and the knee joint is one of the most stressed joints, which predisposes it to more frequent trauma, accounting for approximately 60% of all injuries in sportspeople (Dvorak et al., 2011; Vauhnik et al., 2011). The risk of suffering an ACL tear is lower in the overall population (Mountcastle et al., 2007), but noticeably higher in team sports such as football (Waldén et al., 2011). Only 24% of all soccer lesions are isolated ACL tears (Vauhnik et al., 2011), being a troublesome trauma for a player with potentially negative long-term physical and psychological impacts (Filbay & Grindem, 2019). This type of ligament damage does not only affect top-level athletes as 66% of patients are people practicing sports recreationally (van Melick et al., 2016, Vauhnik et al., 2011). Moreover, approximately 60% of all ACL injuries are caused by the non-contact mechanism (Biały et al., 2022; Vauhnik et al., 2011) and they are more frequent among pivoting sports athletes between 15 and 40 years of age (van Melick et al., 2016). Furthermore, females damage their ACL 2 to 8 times more frequently (Bram et al., 2021; van Melick et al., 2016), which is perhaps due to a different physiological structure of the body and differences in neuromuscular control between genders during adolescence (Myer et al., 2013; Yoo et al., 2010).

The number of ACL reconstruction (ACLR) operations is steadily increasing; the purpose of ACLR is to restore the ligament structure, which is associated with improving the passive stability of the knee joint and increasing its functional capabilities (Filbay & Grindem, 2019; Webster & Hewett, 2019). Patients treated surgically require the implementation of rehabilitation protocols for their return to the pre-injury level of sports performance, which has been an indicator of treatment success. Therefore, the rate of recurrent ACL injury is the most common parameter analyzed in the context of assessing the effectiveness of a surgical procedure and a physiotherapy process. The incidence of re-rupture is still

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high and amounts to 5–11% and 8–21% for the ligament in the operated and contralateral extremities, respectively (Ardern et al., 2014; Brophy et al., 2012; Paterno et al., 2014). The index of return to sport is higher for an elite footballer – around 88% (Lai et al., 2018) – than for a non-elite/professional footballer – around 55% (Ardern et al., 2014). The reasons for these discrepancies seem to be professionally supervised full-time rehabilitation and a higher preoperative level of fitness and strength, along with the financial incentive of getting back into the game (Herrington et al., 2021). The ability to make a safe return to sport is determined by many factors, including postoperative knee function, proprioception, and muscle strength, underestimated social factors, and psychological issues, such as fear of re-injury and motivation (Herrington et al., 2021; Jang et al., 2014).

Therefore, the main feature that characterizes patients after ACLR is the side-to-side differences observed between operated and non-operated extremities during functional activities (Blache et al., 2017). Despite the fact that side-to-side asymmetries are common in the human musculoskeletal system (Adamczyk et al., 2016; Biały et al., 2010; Gnat & Biały, 2015), functional inter-extremity differences may indicate a higher re-injury risk in patients on the basis of delayed recovery of quadriceps strength and neuromuscular control (Culvenor et al., 2017; Greenberg et al., 2014; Herrington et al., 2021).

There are several performance-based tests used to evaluate patients' function and side-to-side symmetry after ACLR. Many of these measures assess the combination of neuromuscular control, muscle strength, and lower extremity confidence, as well as trunk control and the ability to manage external loads. The Functional Movement Screen (FMS) was used by Boyle et al. (2016) to evaluate global movement patterns in adolescent patients who had undergone primary ACLR 9 months postoperatively but it is difficult to find data in the earlier stages after ACLR for that group of patients. Moreover, another important factor for a safe return to sport is muscle status after ACLR. Muscle dysfunction, in terms of strength following surgery, has been identified as a risk factor for re-injury or contralateral knee joint injury (Culvenor et al., 2017; Herrington et al., 2021). Also, quadriceps strength status and inter-extremity asymmetry have been associated with the level of long-term functional performance (Herrington et al., 2021; Pietrosimone et al., 2016).

Isokinetic force measurement seems to be the most appropriate way to assess muscle strength in terms of return to sport (Herrington et al., 2021; van Melick et al., 2016). Patients' functional evaluation after surgery should be based on objective criteria (Biały et al., 2021; van Melick et al., 2016; Waldén et al., 2016) and aim to evaluate factors such as muscle strength, joint stability, neuromuscular control, and the overall function of the lower extremity (Kuszewski et al., 2019; Szlachta et al., 2021). Nevertheless, there is still no consensus concerning objective test protocols granting the safe return to pre-injury training loads along with reducing the risk of renewed injuries after knee surgeries (Gokeler et al., 2017; van Melick et al., 2016). The purpose of this investigation was to assess the functional status of muscle strength and the overall function of the lower extremity in a group of non-elite football players 6 months after ACLR. Assessment of crucial functional parameters such as side-to-side differences in limbs appears to be important at the time when the patient very often decides the return to sport after ACLR (Crossley et al., 2020; Gokeler et al., 2017; Lai et al., 2018). Controlling functional recovery in the process of postoperative rehabilitation should help the physiotherapist treat patients with ligament injuries and provide a safer recovery for them.

Methods

This study was designed as a retrospective review of data collected from a cohort of young and non-elite football players after ACLR. Functional assessment included FMS tests and quadriceps and hamstring peak torques evaluated using the Biodex Testing System. The study was endorsed by the local Research Ethical Committee (No. 3/2017) and all subjects gave written informed consent.

Participants

The research included 35 patients (male:female ratio 31:4; mean age 24.7 ± 2.8 years) who had undergone single-bundle ACLR using autogenous semitendinosus-gracilis tendon graft conducted by an experienced surgeon. The group of subjects was selected after meeting the inclusion criteria: ACLR using semitendinosus-gracilis graft, no history of previous ACLR (both lower extremities), no additional extra or intra-articular repairs (e.g., posterior lateral complex reconstruction or meniscus repair), and no additional surgery or current pain in the hip or ankle joint (for both lower extremities). Demographic characteristics of the patients are presented in Table 1. The time from surgery to examination was 6.1 ± 2.6 months (minimum 3, maximum 12). Patients included in the study played football in a recreational way, not at any competitive level (at least 3 times/week).

Participants did not attend preoperative rehabilitation and after surgery they received a similar standardized rehabilitation program under the supervision of an experienced physiotherapist. Each participant received precise guidelines for ACL rehabilitation in the early postoperative phase, focusing on the knee range of motion, oedema management, muscle strength drills, and exercise progression regimes. The postoperative protocol included supervised physical therapy and exercises (19 sessions) twice a week between 2 and 6 weeks and once a week from 6 weeks to

Table 1 Basic characteristics of the study group (*N* = 35)

Characteristic	Value
Age, years[a]	24.7 ± 2.8 (20–30)
Men/Women[b]	31/4 (88.5/11.5)
Operated side, right/left[b]	16/19 (45.7/54.3)
Body mass, kg[a]	75.0 ± 9.5 (57–92)
Body height, cm[a]	177.5 ± 7.9 (164–195)
Body mass index, kg/m^2 [a]	23.7 ± 1.9 (20.8–27.8)

Note. [a]Values are expressed as *M* ± *SD* (range). [b]Values are expressed as *n* (%).

3 months after surgery, then one session every month till 6 months. Apart from the above, each of the patients received recommendations for daily home exercises.

Procedures

Two raters blinded to the objective of this study were involved in the collection of data on the patients' functional outcome and data processing was carried out by a third independent rater who was not informed about the assumption of the study, the type of patients tested, the type of surgery or the time interval from surgery to functional assessment.

A pilot study was carried out in order to evaluate the level of compliance between raters. The inter-rater reliability of the FMS and isokinetic strength measurements was validated in a group of 12 healthy patients, which resulted in a weighted Cohen's kappa coefficient equal to 0.75 for FMS tests and an intraclass correlation coefficient for isokinetic strength tests (peak torque/body weight ratio, in Nm/kg) ranging from .80 to .94.

The examination of each patient was preceded by a 15-minute warm-up on a bicycle ergometer, during which the rater briefly explained each step of the assessment procedure and asked about their health condition, especially the lack of any musculoskeletal pain symptoms. Subjects were free to terminate the tests if any pain occurred at any stage of the examination.

The first step of the examination procedure was the standardized FMS version. The battery of FMS tests consists of seven dynamic tests to evaluate functional musculoskeletal asymmetries and postural deficits. The quality of fundamental movement patterns was examined on the basis of muscle strength, flexibility, range of motion, and neuromuscular control (Chorba et al., 2010; Minick et al., 2010). Each participant was given three trials for each of the seven tests (the deep squat, in-line lunge, hurdle step, shoulder mobility, active straight leg raise, trunk stability push-up, and quadruped rotary stability). Each test is scored from 0 to 3 points using specific evaluation criteria, with the aim to pinpoint deficient areas of mobility and stability. Specific scoring of these tests has been outlined in prior studies and text (Minick et al., 2010). The result of the best trial was evaluated. The total possible score ranged from 0 to 21 (the sum of scores from 7 tests). The FMS has been verified to be reliable (Minick et al., 2010; Teyhen et al., 2012). Additionally, this study focused on the total FMS result as an appraisal index for functional asymmetries and global pattern deficits.

The next step of the procedure was the evaluation of muscle performance determined using a Biodex System 4 (Biodex Medical Systems, Shirley, NY, USA). Isokinetic knee flexion and extension peak torques were tested for both legs at an angular velocity of 60 deg/s and 180 deg/s. The operated (OP) and non-operated (NOP) extremities were assessed while the subjects were positioned on the seat of the dynamometer, and stabilized by belts around their trunk, pelvis, and thighs; a resistance pad was placed at a level approximately 3 cm proximal to the medial malleolus. All participants underwent an examination of the NOP limb first. Bilateral isokinetic knee extensor and flexor analysis was accomplished with the protocol at 60 deg/s (5 repetitions) and 180 deg/s (5 repetitions) and gravity correction (Undheim et al., 2015). There was a rest of 1 minute between each trial and all tests were performed by the same researcher.

Data were collected for mean peak torque which indicates the muscle's maximum strength capability in the OP and NOP extremities. However, the assessed parameter was peak torque related to body weight (PT/BW ratio, in Nm/kg) which is more relative and pertinent to functional activity (Pietrosimone et al., 2016; Undheim et al., 2015). Additionally, to determine discrepancies in muscles strength between OP and NOP limb for flexion and extension at both angular velocities, the limb symmetry index (LSI) was calculated according to the formula: LSI = result for OP leg/result for NOP leg * 100 (Wellsandt et al., 2017).

Statistical analysis

Due to the outcomes showing no significant deviations from a normal distribution, parametric statistics was applied. Inter-extremity differences described by the PT/BW ratio between OP and NOP limb at angular velocity of 60 deg/s and 180 deg/s were compared with use of the paired *t*-test and the significance level was set at a $p < .05$. Moreover, effect size was assessed using Cohen's d with interpretation: small ($d = 0.2$), medium ($d = 0.5$), and large ($d \geq 0.8$; Cohen, 1988). Statistica software (Version 12; StatSoft, Tulsa, OK, USA) was used for all calculations.

Results

The overall score of FMS tests in the group of subjects was 15.34 ± 2.60 points. Statistical analysis of the functional outcomes of the individual isokinetic strength tests showed significant differences between the OP and NOP extremities. For the isokinetic tests, the divergences revealed were constantly relevant (Table 2).

The values of PT/BW for quadriceps at both angular velocities were significantly higher for NOP compared to OP. The outcome for the movement of extension was at an angular velocity 60 deg/s 2.07 vs. 2.78 Nm/kg ($p < .001$, $d = 0.73$) and at angular velocity 180 deg/s 1.56 vs. 1.98 Nm/kg ($p < .001$, $d = 0.56$).

Table 2 Means, standard deviations, ranges, and statistical significances for inter-extremity comparisons

	Extremity		
Peak torque (Nm/kg)	Operated	Non-operated	p
Angular velocity 60 deg/s			
Extension	2.07 ± 0.59 (0.83–3.42)	2.78 ± 0.37 (1.97–3.74)	< .001
Flexion	1.28 ± 0.30 (0.41–2.03)	1.46 ± 0.26 (1.00–2.09)	< .001
Angular velocity 180 deg/s			
Extension	1.56 ± 0.44 (0.58–2.34)	1.98 ± 0.31 (1.53–2.61)	< .001
Flexion	1.05 ± 0.24 (0.51–1.59)	1.22 ± 0.23 (0.75–1.66)	< .001

Furthermore, the score of PT/BW for hamstrings was also relevant and higher for NOP compared to OP. Results observed for the hamstrings were at an angular velocity 60 deg/s 1.28 vs. 1.46 Nm/kg (p < .001, d = 0.30) and at angular velocity 180 deg/s 1.05 vs. 1.22 Nm/kg (p < .001, d = 0.35).

Recorded peak torques were always lower in the OP extremity regardless of angular velocity or movement direction. LSI results for PT/BW at 60 deg/s were 75% in extension and 88% in flexion and at 180 deg/s were 79% in extension and 86% in flexion.

Discussion

In this study, our purpose was to assess the functional status of young non-elite football players 6 months after ACLR and to detect potential side-to-side asymmetries between OP and NOP extremities.

The evaluated FMS battery of tests originally was developed to assess functional movement on the basis of sufficient muscular strength and proper motor control. Moreover, the FMS sum score has been used as an index to predict injury risk, where a low score means a higher risk of injury. The usefulness of this test has been called into question, however; to reduce error in screening, specialists suggest that researchers should be instructed about and familiar with the screening tool (> 100 trials; Kraus et al., 2014). Nevertheless, utilization of the FMS battery of tests in detecting side-to-side asymmetries in adult patients after ACLR was recently examined by Biały et al. (2022). Their findings suggest that the use of the FMS tests in the early phase after ACLR can lead to an overestimation of the functional status and might expose patients to excessive loads during treatment. In our research, the mean total FMS score was 15.34 ± 2.6, showing better functional outcomes compared to the investigation of Mayer et al. (2015) who evaluated adult patients 6 months after ACLR and found no significant difference in the FMS test results between the patients who were clinically cleared for return to sporting activities without restriction (total FMS score 12.7 ± 2.9) and those who were not (total FMS score 12.8 ± 2.7). The outcomes of this study are above the injury predictive threshold of 14 and similar to the normative value of 15.7 ± 1.9 published by Schneiders et al. (2011) in a young, active, and healthy uninjured population.

Deficits in quadriceps and hamstring activation and muscle strength have been commonly found in patients who have undergone ACLR. The majority of these individuals show moderate to large significant weaknesses in quadriceps and hamstring power when compared to the NOP extremity. Herrington et al. (2021) reported that these deficiencies can persist for more than 2 years after the operation and the decrease in muscle function may result in diminished athletic performance as well as adversely affecting daily living and quality of life (Culvenor et al., 2017; Dębski et al., 2019; Flosadottir et al., 2016). Therefore, it seems crucial to employ a diagnostic tool that is safe at each stage of recovery after ACLR and also allows the detection of side-to-side asymmetries for a safe and effective rehabilitation process (Linek et al., 2016).

Our conclusions are similar to those drawn from previous research results described by Herrington et al. (2021) who reported large significant deficits in isokinetic quadriceps strength at the time of return to full-time unrestricted play in OP extremities among elite football players. We assumed that, at the post-ACLR treatment stage selected for functional assessment, the OP extremity would show worse functional outcomes due to its incomplete recovery. According to muscle status, the researchers observed that the OP extremity was always weaker in terms of quadriceps and hamstring strength described by PT/BW ratios at the time of measurement. All registered LSI values, regardless of angular velocity and movement direction, were below 90%. One of the important return-to-sport criteria is an LSI > 90 % for isokinetic quadriceps and hamstring strength at 60°/s and 180°/s (Gokeler et al., 2017; Thomeé et al., 2011; Wellsandt et al., 2017). Our results are in agreement with the findings of a systematic review showing that 6–9 months post-ACLR, patients had significantly lower muscle strength with differences in LSI between 16% and 39% and were, therefore, not within the acceptable LSI limit (Larsen et al., 2015). Thus, greater attention should be paid to recovering full muscle performance. However, Wellsandt et al. (2017) presented interesting findings about overestimating LSI in assessing knee function after ACLR. The authors of the study demonstrate that achievement of limb symmetry in quadriceps strength after ACLR does not guarantee that prior functional status has been met. This indicates the need for further investigation of the optimal battery of tests.

There are several limitations of this study. First, due to its post-surgery character, we were unable to collect preoperative functional outcomes. Having these data would have provided a baseline measurement with which to compare changes over time postoperatively. Secondly, our study was conducted only on generally young, physically active recreational athletes, thus attempts to generalize the results should be made with due care. On the other hand, the innovation of this study may be the isokinetic strength assessment by muscle peak torques normalized to body weight.

The clinical application of the presented results could be significant in the context of the progression of physiotherapy programs after ACLR. Nevertheless, in a group of young and non-elite football players, a series of FMS tests can be used for musculoskeletal screening and motion analysis in the process of recovery after surgery. Detecting global pattern deficits might help in the safe management of patients after ACLR and their return to sports activity. However, the use of isokinetic strength tests could be more useful in detecting muscles asymmetry between the OP and NOP extremities, which is important in the context of the risk of re-injury. Due to the lack of consensus as to the moment when the patient is ready to return to full activity, it seems obvious that this area requires further research.

Conclusions

In the group of young and non-elite football players about 6 months post-ACLR, it is possible to detect significant functional inter-extremity differences in performing isokinetic strength tests which reveals that the OP extremity is significantly weaker regardless of angular velocity or movement direction. Delayed recovery of muscle function of the OP extremity and disparities between extremities at a time when often patients subjectively feel ready to return to sport after ACLR can indicate a potentially higher risk of re-injury. Practical application of the presented results could be significant in the context of the progression of physiotherapy programs after ACLR with the use of the isokinetic strength test in detecting muscle strength asymmetry between the OP and NOP extremities and FMS to identify disturbances in global movement patterns after ACLR.

Conflict of interest

The authors report no conflict of interest.

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