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Are athletes able to resume sport at six-month mean follow-up after anterior cruciate ligament reconstruction? Prospective functional and psychological assessment from the French Anterior Cruciate Ligament Study (FAST) cohort

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ABSTRACT

Background: The decision to return to sport following anterior cruciate ligament (ACL) reconstruction should not only be based on time since surgery. This study aimed to assess, using isokinetic and neuromuscular (hops) testing in a large group, postoperative objective functional recovery of the knee. The secondary objective was to determine the relationship between psychological, functional scores, and these postoperative tests.
Methods: This prospective study included athletes who underwent surgery between 2013 and 2016 for an isolated full-thickness ACL tear. They received a complete evaluation of functional performance of the knee by isokinetic tests performed on a dynamometer to measure quadriceps and hamstring strength, and neuromuscular assessment based on single-leg hop tests. The main judgment criterion was satisfactory functional recovery (yes/no) defined as a difference of ≤10% both in the quadriceps 60°/s and the single hop at a minimum of four months of follow-up.
Results: A total of 234 athletes were analyzed. The mean age was 28.4 ± 8.6 years. At 6.5 ± 1.7 months mean follow-up, 44 (18.5%) patients had satisfactory functional recovery of the knee. The correlations between isokinetic/hop tests and the different scores were variable. During follow-up, two patients presented with a graft tear and two with a contralateral ACL tear, all in the group with unsatisfactory functional recovery.
Conclusion: At a mean of six months after ACL reconstruction, objective functional recovery of the knee was generally unsatisfactory and this seemed to be a risk factor for recurrent tears.
Level of evidence: IV; case series.

1. Introduction

The decision to return to sport following anterior cruciate ligament (ACL) reconstruction is too often based on the time elapsed since surgery, with a well-known six-month delay. The systematic review of the literature by Barber-Westin and Noyes show that

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32% of published studies used time factor as the only criterion for the decision to return to sport, and 13% based this decision on objective individual criteria [1]. Although there is no consensus as to which tests to use to predict a successful return to sport [2,3], isokinetic and hop tests are the most frequently used objective criteria in the literature [1,3,4]. These tests quantify the muscular and functional performance of the knee to identify any differences between the operated and healthy knees [5]. They are reliable, valid and reproducible [6–9]. Moreover, isokinetic and hop tests are complementary and correlated, providing an analytical assessment of muscular strength as well as the neuromuscular capacity of the knee [10]. A recent meta-analysis confirmed the value of using these two series of tests together [11]. The accepted cut-off value of a 10% deficit compared with the contralateral knee is used to classify patients with satisfactory functional recovery (deficit ≤10%) and unsatisfactory functional recovery (deficit >10%) of the knee [11–13].

Certain athletes do not return to sport despite scores showing satisfactory functional recovery. Several studies have shown that the fear of a recurrent tear is one of the most frequent reasons for athletes failing to return to sport [14]. The Anterior Cruciate Ligament-Return to Sport after Injury (ACL-RSI) scale quantifies the influence of psychological factors on the patient's ability to return to sport [15,16]. This questionnaire was developed in relation to three elements that have been correlated with returning to sports: emotions, confidence in one's performance, and evaluation of risk. The ACL-RSI scale includes 12 questions and high scores correspond to a positive psychological response.

The main goal of the current study was to assess postoperative objective functional recovery using isokinetic and neuromuscular (hops) testing in a large group, a mean six months after surgery. The secondary objective was to determine the relationship between functional scores, psychological ACL-RSI score, and postoperative isokinetic and hop testing. The main hypothesis was that most patients would have satisfactory postoperative functional recovery at six months, justifying a decision to return to sport.

2. Methods

A single-center, prospective study (French prospective Acl STudy [FAST]) was begun in 2012. It included all patients who were operated for reconstruction of the cruciate ligaments by four senior surgeons. The study was approved by the ethics committee and all patients gave informed consent. The study was declared on the site clinicaltrial.gov (Identifier: NCT02511158).

2.1. Patient selection criteria

All athletes (men and women), whatever their level of sport, who underwent surgery between 2013 and 2016 by four senior surgeons for an isolated full thickness ACL tear and who received complete postoperative isokinetic and functional testing in the same physiotherapy department were included. Patients with a history of severe disease in both knees that could disturb the measurements were not included (a history of ligament tears in one of the knees, combined ligament lesions, or recent muscular injuries), prior surgery in a knee and patient refusal.

2.2. Study protocol

The same surgical, anesthesia, analgesia and rehabilitation protocol was used for all patients. Surgery was performed under spinal or general anesthesia, according to the patient's wishes. Surgery was performed by arthroscopy using the semi-tendinosus-gracilis (ST-G) graft technique, the ST alone (quadruple stranded or ST4), or the patellar or fascia lata tendons. Extra-articular reinforcement of the fascia lata could be associated with ACL reconstruction if the surgeon felt it was needed for knee stability [17]. Only autografts were used. Postoperative rehabilitation was based on strengthening the quadriceps and hamstrings, and functional exercises for neuromuscular control of the knee [18]. The rehabilitation protocol consisted of five successive phases. During the first three weeks, the protocol included muscular extension work in supine position, gentle mobilization, massage, ice and electrostimulation. From the 21st to the 45th day, weight bearing was progressed without help, gait re-education to the march was carried out, associated with moderate and progressive muscular activities in contraction, static bipodal then unipodal balance (balneotherapy), and cycling without resistance and treadmill walking at the end of this phase. From the 45th day to the fourth month, the muscular work of the quadriceps and hamstrings was intensified in closed kinetic chain and isometric extension–contraction, with development of neuromuscular control and proprioception (trampoline, unstable plateau), cardiovascular exercise training (cycling, steps) and running on a flat surface. From the fourth to sixth months, muscular work was strengthened by isokinetic work, dynamic work with jumps and direction changes, running with accelerations, crawl-style swimming, cycling and progressive physical reintegration activities. Beyond the sixth month, the goal was to direct rehabilitation towards specific sport practice.

2.3. Functional assessment protocol

Postoperative functional testing could be performed from four months after surgery. The knee had to be dry (no knee joint effusion), without pain, swelling or sensitivity, and with full functional range of motion. Function was evaluated using analytical muscular strength tests (isokinetic tests) as well as neuromuscular control tests (hop tests). The same therapist performed the two groups of tests consecutively on the same day. Each test was repeated three times and the maximum of the three values was recorded.

2.3.1. Isokinetic tests

An isokinetic dynamometer (Con-Trex® MJ; CMV AG, Dubendorf, Switzerland) was used to test the muscular strength of the quadriceps and hamstrings with a standardized protocol (Figure 1) [19]. The peak torque (maximum muscular effort) of the quadriceps was measured at angular velocities of 60°/s (slow velocities) and 240°/s (rapid velocity) for concentric exertions, then the hamstrings at 30°/s for eccentric exertions and the ratio hamstring (HS) 30° eccentric/quadriceps (Q) 240° for concentric exertions. The percentage of difference between the operated side and contralateral side was used to determine the percentage of asymmetry.

2.3.2. Single-leg hop tests

After the isokinetic test and five minutes of rest, four hop tests were performed according to Noyes et al. in the following order: single hop test for distance, triple hop test for distance, triple cross-over hop test for distance, and six-meter timed hop test (Figure 2) [20]. The difference between the operated side and healthy side was calculated (in distance or time) and presented as a percentage.

2.4. Follow-up protocol

Demographic data and the isokinetic test and functional test results were recorded for each patient (on an Excel table) on the day of the test. Questionnaires were answered online by the patient with websurvey.fr® software at postoperative month six (±1 month). These questionnaires included the ACL-RSI [16], International Knee Documentation Committee (IKDC) Subjective Knee [21], Lysholm [22], and Knee injury and Osteoarthritis Outcome Score (KOOS) scores [23]; return to sport (running, pre-injury sport and delay to return to sport) during the first postoperative year (six-month and one-year follow-ups) was also included.

2.5. Evaluation criteria

The main evaluation criterion was postoperative functional recovery characterized by the percentage of difference in the quadriceps between the healthy leg and injured leg for concentric efforts at 60°/s and on the single-leg hop test at four months. The cut-off point was a deficit of 10% in these two tests [11]. Two groups were created: those with a satisfactory functional recovery (deficit ≤10% on these two tests) and those with an unsatisfactory recovery (deficit >10% on at least one of the two criteria) according to the study investigators.

Secondary judgment criteria were the correlation at six months between the isokinetic and neuromuscular tests and the different knee scores (ACL-RSI, subjective IKDC, KOOS and Lysholm scores), identification of any risk factors for unsatisfactory recovery, return to sport during the first postoperative year (running and practice of the same pre-injury sport), level of play judged subjectively by the patient in relation to his/her best level before injury (worse/the same/better), and recurrent tears – either of the graft or the contralateral ACL – during the first year after surgery.

Figure 1. Isokinetic dynamometer and installing the patient.

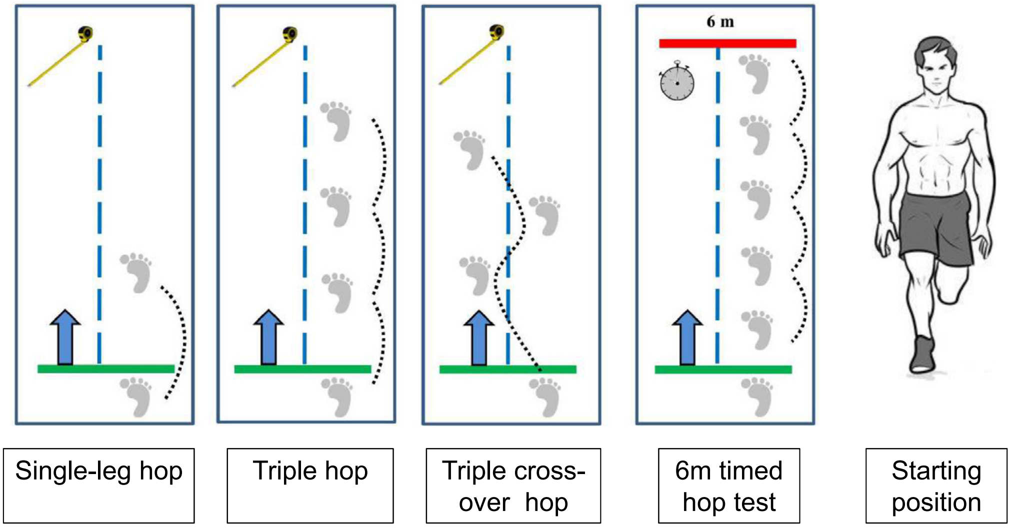

Figure 2. Single-leg hop tests.

2.6. Statistical analysis

Statistical analyses were performed with STATA.10 software. Normal distributions were tested by the Shapiro–Wilk test. The Student *t*-test for independent and paired groups (before/after) was used for quantitative variables and the Chi-squared test for qualitative variables. All correlations were evaluated by Pearson's correlation coefficient as strong ($r > 0.5$), good ($0.5 < r < 0.3$) or weak ($0.3 < r < 0.1$) [24]. The number of patients was estimated to obtain a Pearson correlation coefficient of $\rho = 0.8$, with a confidence interval of $\omega = 0.15$ and an alpha risk of $\alpha = 0.05$ [25]. The confidence interval (CI) was (0.712, 0.863) with a width of 0.152. Thus, *N* was at least 93.833266872111 and the size of the cohort was 94. Taking into account that five percent of questionnaires would not be filled in or be incomplete, at least 100 patients were needed for analysis. A *P*-value of 0.05 was considered to be significant.

3. Results

3.1. Demographic patient characteristics

A total of 234 patients, mean age 28.4 ± 8.6 years (15–50) were included. There were 173 men and 61 women. Mean body mass index (BMI) was 23.6 ± 3.3. The series included seven (3.0%) professional athletes, 111 (47.4%) competitive athletes, 97 (41.5%) regular recreational athletes, and 19 (8.1%) occasional recreational athletes. Different sports were practiced (Figure 3).

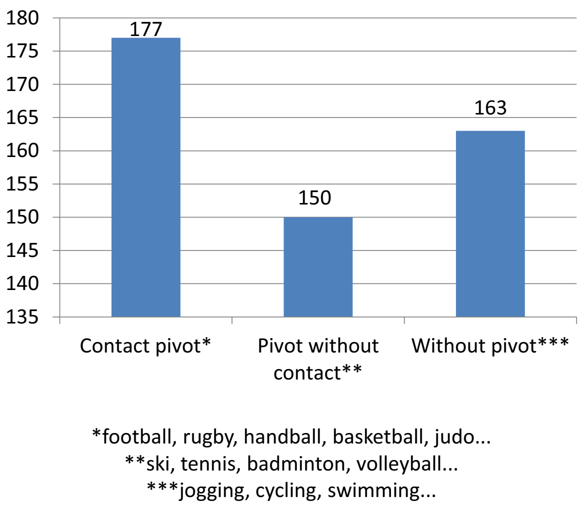

Figure 3. Sports practiced (often more than one sport per patient).

The causes of the injuries reported by 217 patients were a sports accident (89.9%), work-related accident (5.5%), road accident (23.0%) or domestic accident (2.3%).

Three types of grafts were used: hamstrings (82.9%), fascia lata (10.7%) and patellar tendon (6.4%). Moreover, 66 patients (28.2%) underwent extra-articular reinforcement for stabilization.

3.2. Postoperative functional recovery

Objective assessment of functional recovery was obtained a mean 6.5 ± 1.7 months (four to 12) after surgery. Functional recovery was satisfactory in 44 patients (18.5%), that is these patients had a deficit ≤10% between the two limbs for concentric quadriceps strength at 60°/s as well as for the single-leg hop test. The study hypothesis was rejected.

Fifty-two patients (22.2%) had satisfactory muscle strength: a deficit of ≤10% in concentric quadriceps strength at 60°/s compared with the healthy knee. Patients had a mean deficit of 24% (−83 to +47%) compared to the contralateral side. A total of 125 patients (53.4%) had a deficit of <10% in the single-leg hop test. The mean deficit in this test was approximately 12% (−72 to +35%) (Table 1). The ratio of hamstrings 30° eccentric/quadriceps 240° concentric varied from 0.5 to three. The spread was less marked in the group of patients with satisfactory functional recovery than in those with unsatisfactory recovery (Figure 4).

Univariate analysis did not identify any risk factors for unsatisfactory functional recovery a mean six months after surgery (Table 2).

3.3. Correlations with various functional scores and ACL-RSI

Isokinetic and hop tests were positively and significantly correlated with the different functional scores, except eccentric hamstring muscle strength at 30/s (Table 3). The ACL-RSI score was positively and significantly but weakly correlated with isokinetic and hop tests ($r = 0.15–0.18$, $P = 0.01–0.03$), except for eccentric hamstring muscle strength 30/s ($r = 0.005$, $P = 0.51$) and for the triple crossover for distance ($r = 0.13$, $P = 0.06$) for which no correlation was found (Figure 5). There was a strong correlation between the strength of quadriceps at 240°/s and the subjective IKDC score. This functional score seemed to be a good index of quadriceps strength. No significant correlation was found between eccentric hamstring strength and all subjective functional scores. Therefore, an objective assessment of the hamstring appears to be mandatory. Correlations between all the subjective functional scores and single and triple hop tests were comparable. Thus, it appears to be sufficient to perform one of these two hop tests. Functional scores at the six-month follow-up were significantly better than pre-operative scores (Table 4).

3.4. Return to sport and the level of play during the first year after surgery

Half of the patients (49.1%) in the cohort returned to running after a mean 6.5 months and one third of the patients (33.3%) returned to the same pre-injury sport after a mean 8.7 months. No significant difference was found between satisfactory and unsatisfactory functional recovery groups either for running ($P = 0.33$) or return to the same pre-injury sport ($P = 0.22$). The ACL-RSI score was significantly higher in patients who returned to running (65.2 ± 18.6%) than in those who did not (51.6 ± 22%) ($P = 0.0001$), as well as in patients who returned to the same sport (72.5 ± 16% vs. 58.9 ± 20.7%) ($P = 0.0003$). No significant difference was found in the ACL-RSI score for the levels of functional recovery: 64.2 ± 21.2 in satisfactory group vs. 60.7 ± 20.8 ($P = 0.37$).

Functional recovery was significantly more often satisfactory at a mean six months after surgery in the 78 patients who returned to the same pre-injury sport at the same or a higher level of play, both for concentric quadriceps strength at 60°/s (66.7% vs. 38.6%, $P = 0.03$) and the single-leg hop test (56% vs. 28.6%, $P = 0.02$).

Table 1
The isokinetic and single-leg hop tests values.

Tests in 234 patients	Deficit ≤10% Number of patients (%)	Mean value (minimum to maximum)
Quadriceps 60°/s concentric	52 (22.2%)	−24.16 (−83 to 47)
Quadriceps 240°/s concentric	77 (32.9%)	−18.61 (−79 to 27)
Hamstrings 30°/s eccentric	81 (34.6%)	−16.10 (−60 to 76)
Single-hop test	125 (52.6%)	−12.36 (−72 to 35)
Triple hop test for distance	125 (54.3%)	−11.90 (−67 to 35)
Triple cross-over hop test for distance	136 (60.4%)	−10.05 (−59 to 21)
6-m timed hop test	133 (59.1%)	−10.96 (−72 to 19)

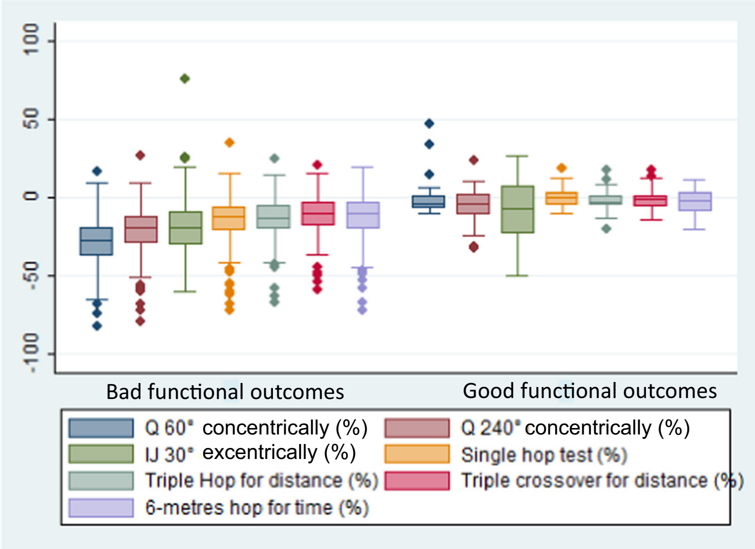

Figure 4. Box plot using the median of functional tests in the satisfactory (1) and unsatisfactory (0) functional recovery groups.

3.5. Recurrent tears during the first year after surgery

Four patients with unsatisfactory functional recovery presented with a tear during the first postoperative year: two graft tears and two ACL tears in the contralateral knee but with no significance between the satisfactory and unsatisfactory recovery groups ($P = 0.34$). These tears all occurred in patients who had returned to running or same sport: three competitive athletes and one regular leisure. This represented 1.7% of the total cohort. There were no graft tears or ACL tears in the contralateral knee in the group with satisfactory functional recovery.

4. Discussion

The main finding of this study was that one in five patients had satisfactory functional recovery of the knee a mean six months after primary ACL reconstruction. This study also showed that the ACL-RSI score was positively and significantly correlated with isokinetic tests of the knee and single-leg hop tests. However, this correlation was weak, which shows that the patient's psychological readiness to return to sport is not only dependent upon the objective physical recovery of the knee.

According to certain authors, a patient is not ready to return to play without contraindications unless there is a deficit of ≤10–15% in quadriceps strength and 15% in the single-leg hop test [1,26]. In the current study, the cut-off of ≤10% was reached in 22% of patients for muscular strength and nearly 53% for the single-leg hop test six months after surgery. In the study by Palmieri-Smith and Lepley, 20% of the patients had a deficit of <10% in muscular strength six to seven months after the end of the rehabilitation program [27]. In the systematic review by Abrams et al., the mean deficit in quadriceps strength at postoperative month six

Table 2
Comparative analysis between satisfactory and unsatisfactory functional recovery groups.

	Satisfactory recovery ($n = 44$)	Unsatisfactory recovery ($n = 190$)	*P*
Age (years)	26.8 ± 8.8	28.8 ± 8.5	0.17
Gender female/male	9/35	52/138	0.35
Body mass index	22.8 ± 3.1	23.8 ± 3.3	0.08
Level of sports practice	Professional = 1 (2.3%)	Professional = 6 (3.2%)	0.98
	Competitive = 21 (47.7%)	Competitive = 90 (47.4%)	
	Regular leisure = 18 (40.9%)	Regular recreational = 79 (41.6%)	
	Occasional leisure = 4 (9.1%)	Occasional recreational = 15 (7.5%)	
Graft	HS[a] = 40 (90.9%)	HS = 154 (81%)	0.27
	FL[b] = 2 (4.6%)	FL = 23 (12.1%)	
	PT[c] = 2 (4.6%)	TP = 13 (6.8%)	
Associated extra-articular reinforcement	10 (22.7%)	56 (29.5%)	0.37
Delay to testing (months)	6.7 ± 1.7	6.4 ± 1.7	0.40

[a] Hamstring.
[b] Fascia lata.
[c] Patellar tendon.

Table 3
Correlation coefficients of functional scores at six months of follow-up and isokinetic and hop tests.

	Q60° concentric	Q240° concentric	HS30° eccentric	Single hop	Triple hop for distance	Triple cross-over for distance	6-meter hop for time
Subjective IKDC (%)	$r = 0.41$ *(Good)* $P < 0.00001$	$r = 0.50$ *(Strong)* $P < 0.00001$	$r = 0.04$ (NS) $P = 0.63$	$r = 0.40$ *(Good)* $P < 0.00001$	$r = 0.42$ *(Good)* $P < 0.00001$	$r = 0.31$ *(Good)* $P < 0.00001$	$r = 0.29$ *(Weak)* $P < 0.00001$
KOOS symptoms and stiffness	$r = 0.18$ *(Good)* $P = 0.01$	$r = 0.26$ *(Weak)* $P = 0.0003$	$r = -0.005$ (NS) $P = 0.95$	$r = 0.19$ *(Weak)* $P = 0.01$	$r = 0.19$ *(Weak)* $P = 0.01$	$r = 0.17$ *(Weak)* $P = 0.02$	$r = 0.08$ (NS) $P = 0.30$
KOOS pain	$r = 0.19$ *(Weak)* $P = 0.008$	$r = 0.31$ *(Good)* $P < 0.00001$	$r = -0.04$ (NS) $P = 0.60$	$r = 0.22$ *(Weak)* $P = 0.003$	$r = 0.24$ *(Weak)* $P = 0.001$	$r = 0.15$ *(Weak)* $P = 0.04$	$r = 0.20$ *(Weak)* $P = 0.006$
KOOS daily life	$r = 0.26$ *(Weak)* $P = 0.0004$	$r = 0.37$ *(Good)* $P < 0.00001$	$r = 0.009$ (NS) $P = 0.91$	$r = 0.32$ *(Good)* $P < 0.00001$	$r = 0.33$ *(Good)* $P < 0.00001$	$r = 0.22$ *(Weak)* $P = 0.003$	$r = 0.31$ *(Good)* $P < 0.00001$
KOOS sport	$r = 0.31$ *(Good)* $P < 0.00001$	$r = 0.41$ *(Good)* $P < 0.00001$	$r = -0.06$ (NS) $P = 0.43$	$r = 0.34$ *(Good)* $P < 0.00001$	$r = 0.34$ *(Good)* $P < 0.00001$	$r = 0.31$ *(Good)* $P = 0.00002$	$r = 0.30$ *(Good)* $P = 0.00008$
KOOS quality of life	$r = 0.21$ *(Weak)* $P = 0.003$	$r = 0.24$ *(Weak)* $P = 0.0009$	$r = -0.02$ (NS) $P = 0.78$	$r = 0.23$ *(Weak)* $P = 0.002$	$r = 0.22$ *(Weak)* $P = 0.003$	$r = 0.21$ *(Weak)* $P = 0.005$	$r = 0.20$ *(Weak)* $P = 0.007$
Lysholm	$r = 0.33$ *(Good)* $P < 0.00001$	$r = 0.41$ *(Good)* $P < 0.00001$	$r = 0.05$ (NS) $P = 0.48$	$r = 0.31$ *(Good)* $P = 0.00002$	$r = 0.39$ *(Good)* $P < 0.00001$	$r = 0.29$ *(Weak)* $P = 0.00008$	$r = 0.30$ *(Good)* $P = 0.00003$

IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score.

was >20%, and the patients did not reach quasi-symmetric quadriceps strength (deficit ≤10%) until 1.5 years of follow-up [3]. Although the use of the 10% cut-off for isokinetic tests is severe, there is consensus on this threshold in patients who wish to return to high-intensity sport without contraindications [9,10,28]. Certain authors recommend that athletes recover 100% of their strength for pivot-contact sports [29].

In the literature, the factors favoring excellent results for isokinetic and hop tests at six months are younger age, a low BMI, and minimal cartilage degeneration [30]. The current study did not identify any risk factors, in particular age, which was also true of the study by Kobayashi et al. [31]. In the current study the graft harvesting site was also not found to be a factor. According to literature, reconstruction using a hamstring graft may result in a decrease in flexion strength, while a decrease in extension strength may occur with a patellar tendon graft [32,33].

In the current study, about half of the patients returned to running within 6.5 months of surgery, independent of their level of functional recovery. However, when the functional recovery was deemed unsatisfactory by the surgeon, the patient was not allowed to resume sport. This study has shown through self-questionnaires that patients can resume sport despite the unfavorable opinion of the surgeon. Moreover, one third of the patients returned to their pre-injury sport within nine months of surgery, including 41% with satisfactory functional recovery and 32% with unsatisfactory functional recovery, which shows that surgeons' recommendations are not always followed by patients. This difference was not significant. Nevertheless, a mean delay of approximately two months between the tests and return to sports may create a bias in this interpretation.

The current study showed that there was a relationship between the level of play in patients who returned to the same sport and functional recovery after a mean six months. A return to the same sport at the same or a higher level was favored by good results in the test measuring quadriceps strength and/or the single-leg hop test. Schmitt et al. also found that a quadriceps strength deficit of >10% resulted in a decrease in physical performance and thus greater difficulty in reaching the same level of pre-injury play [10].

In the current study, four recurrent tears (1.7%) were observed during the first year of surgery: two graft tears and two contralateral ACL tears, all in the group of patients with unsatisfactory functional recovery — this difference was statistically not significant. Return to a high-intensity activity is the primary risk factor for recurrent or contralateral tears [34]. When neuromuscular control is altered (dynamic valgus, internal rotation of the knee or limited flexion during landing), the risk of a recurrent tear is increased [34,35].

The ACL-RSI is the first score to specifically evaluate the influence of the psychological state on return to sport following ACL reconstruction [15]. Ardern et al. also reported that patients who had not returned to sport at one year had negative emotions, less confidence in their athletic ability, and were at a higher risk of having a recurrent tear when returning to sport than patients who had already returned to play [36]. All patients in the current study who had a re-tear were in the unsatisfactory recovery group so the impact of an insufficient ACL-RSI score in the occurrence a recurrent tear in patients with satisfactory functional recovery could not be quantified.

Based on these findings, there are two take-home messages. First, before considering a return to sport, assessment of the patient must be complete — both objective with isokinetic tests and single-leg hops and subjective with various functional and psychological scores. In case of insufficient functional recovery, these assessments must be repeated before allowing a patient to return to sport. Second, each patient must be managed individually with a multidisciplinary approach involving various healthcare professionals: surgeons, physiotherapists and sport psychologists.

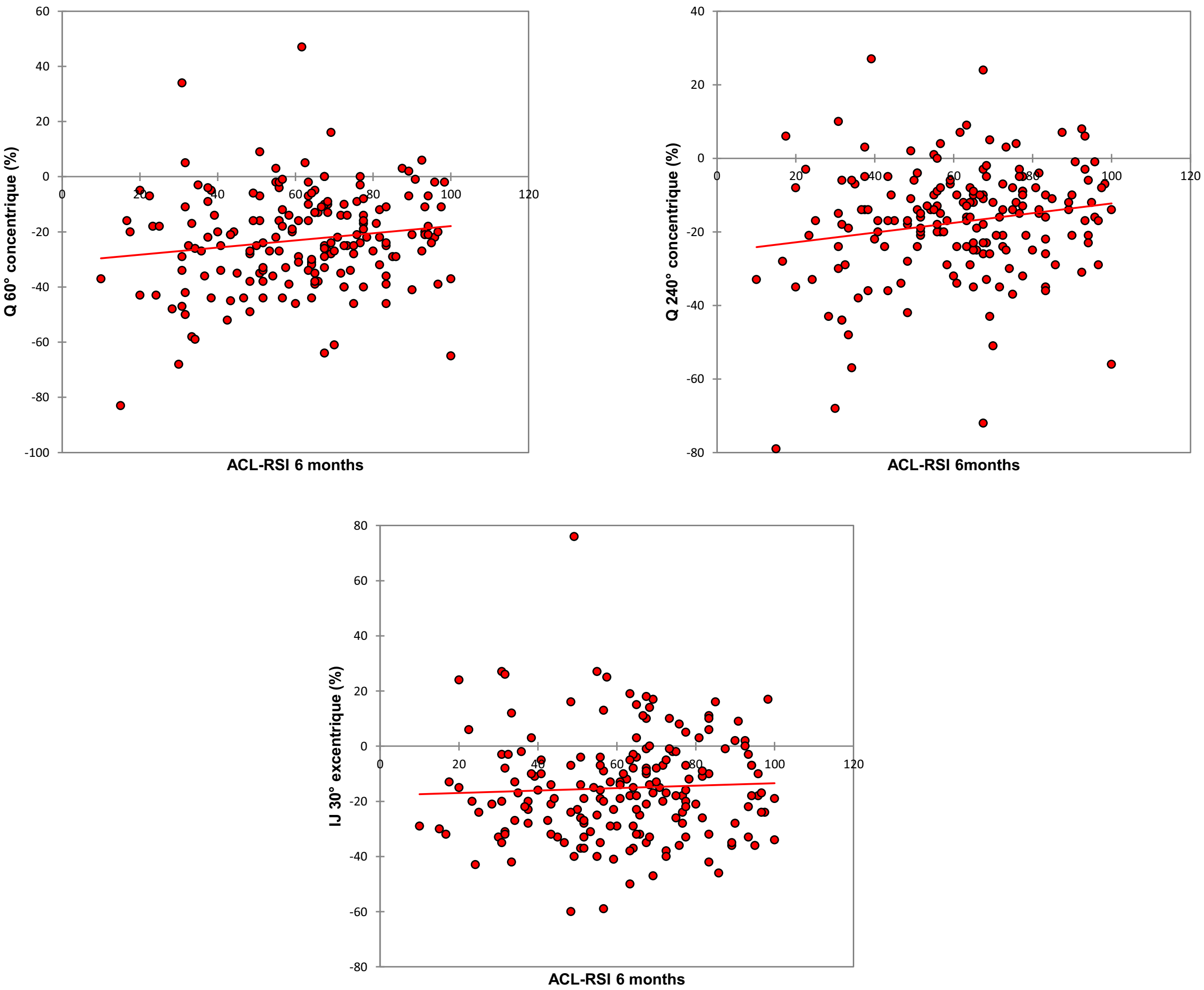

Figure 5. Linear regression between the Anterior Cruciate Ligament-Return to Sport after Injury score and postoperative isokinetic and hop testing.

This study had several strengths. The ability of patients to resume sport was assessed in a large series and from several angles: isokinetic tests, single-leg hop tests, functional and psychological scores. Data collection was systematic and complete. The isokinetic and single-leg hop tests that were used have been validated and are recommended to evaluate functional recovery of the knee following ACL reconstruction [3,37]. The cut-off point of ≤10% used in this study is more discriminant than other studies using a cut-off of ≤15% or even ≤20%. Composite judgment criteria were used, including two functional tests to define satisfactory functional recovery. These test provided complementary information because isokinetic tests are analytical and lack the specificity of active athletic movements, which can be obtained with single-leg hop tests.

Table 4
Pre-operative and six-month functional scores.

Scores	Pre-operative	6 months	*P*
ACL-RSI	40.2 ± 22.1	60.2 ± 20.9	0.00001
Subjective IKDC (%)	62 ± 14.3	76.1 ± 11.9	0.00001
KOOS symptoms and stiffness	73.7 ± 16	80.9 ± 15.9	0.00001
KOOS pain	60.7 ± 23.3	88 ± 11.1	0.00001
KOOS daily life	86.9 ± 14.3	95.1 ± 67.4	0.00001
KOOS sports	48.7 ± 25.6	72.3 ± 20.7	0.00001
KOOS quality of life	30.7 ± 18.9	57.7 ± 11.7	0.00001
Lysholm	73.9 ± 14.4	87.1 ± 10.8	0.00001

ACL-RSI, Anterior Cruciate Ligament-Return to Sport after Injury; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score.

This study had several limitations. Tests were performed between four and 12 months after surgery but always before return to sport. The decision to test was based on the clinical status of the knee, rather than the time since surgery. It should also be mentioned that isokinetic tests do not reflect the functional movements used in sports. The effort required on the dynamometer corresponds to open kinetic chain exercises, while most sports activities are more closely approximated by closed chain exercises. These exercises are more strenuous than closed chain exercises in case of injury to ligaments of the central pivot of the knee.

5. Conclusion

This study showed that after a mean follow-up of 6.5 months, one in five patients had satisfactory functional recovery of the knee. The study hypothesis was rejected. During the first year, patients with unsatisfactory functional recovery seemed to have a higher risk of a graft tear or contralateral ACL tear. Therefore, before allowing return to sport, whatever the level of play, it is mandatory to repeat the isokinetic and hop tests in athletes with unsatisfactory functional recovery at six months. The patients with the best chance of returning to the same pre-injury sport at the same or a higher level of play were those with satisfactory objective functional recovery at six months. The ACL-RSI score and an isokinetic, neuromuscular evaluation of the knee after a mean six months after ACL reconstruction were significantly and positively correlated. However, the correlation was weak, which shows that the psychological readiness of the patient to return to sport does not only depend on physical and objective recovery of the knee. A standard rehabilitation protocol should include a psychological evaluation at different periods during follow-up to identify patients who require psychological support. The ACL-RSI scale is a useful and well-adapted objective tool in this context.

Conflict of interest

The authors declare that they have no conflicts of interest.

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IRB

Ethics approval for this study was received from the *Comité de Protection des Personnes Ile-de-France VI (CPP IDF VI)*, Hôpital La Pitié- Salpêtrière.

Trial registration

https://clinicaltrials.gov/, ClinicalTrials.gov Identifier: NCT02511158.

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