



Correlation of Isokinetic Testing and ACL Failure With the Short Graft Tape Suspension Technique at Six Months

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Purpose: The objective of this study was to correlate the data of the 6-month postoperative isokinetic muscle evaluation before resuming sports activities with the occurrence of ACL reconstruction rerupture after semitendinosus short graft. **Methods:** From 2015 to 2018, all patients who were operated for an ACL reconstruction with a short semitendinosus autograft (TLS System) and who performed isokinetic tests on dynamometer at their 6th postoperative month were included in this study. The follow-up was prospective with the measurement of epidemiological, radiographic, and isokinetic parameters at 6 months of the ACL reconstruction. The cohort was divided into 2 groups: one group without an ACL reconstruction rerupture (Group 1) and the second group with a rerupture (Group 2). **Results:** One hundred and four patients were analyzed with an average follow-up of 42.3 months (Minimum: 24; Maximum: 63.5), of which 11 patients (10.6%) had an ACL reconstruction rerupture. Group 1 consisted of 93 patients with an average age of 26.5 ± 9.0 years old who did not have an ACL reconstruction rerupture with an average follow-up of 41.6 ± 12.1 months. Group 2 consisted of 11 patients with an average age of 22.7 ± 6.1 years old, who had an ACL reconstruction rerupture with an average follow-up of 44.8 ± 11.3 months. Concerning extension force recovery, the ratio between operated and healthy knee was $81.8\% \pm 32.0$ for Group 1, and $53.4\% \pm 20.6$ for Group 2 ($P = .035$). A statistically significant difference was also found ($P = .0017$) during $60^\circ/s$ flexion isokinetic test between the two groups. **Conclusions:** This study revealed a significant link between muscle weakness in flexion and extension during $60^\circ/s$ isokinetic test at 6 months of ACL reconstruction and semitendinosus autograft rerupture. Patients with an ACL reconstruction retear had inferior muscle dynamometric recovery results at 6 months before resuming sports activities. **Level of Evidence:** Level III, prognostic, retrospective cohort study.

Introduction

The rates of rerupture after anterior cruciate ligament reconstruction are of the order of 1.7 to 10.3% when considering studies with a minimum 3-year follow-up in cases of semitendinosus/gracilis

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tendons autograft (ST/G).^{1–8} Although mispositioning of bone tunnels is the primary cause of anterior cruciate ligament (ACL) reconstruction rerupture by positive or negative anisometry ranging from 52.2% to 95.6%,^{9–13} the number of risk factors for rerupture are clearly identified in the literature, including genu varum, posterior tibial slope, anterior tibial subluxation and intercondylar notch size.^{14–18} While data on muscle recovery and return-to-sport (RTS) are very well documented,^{19–22} very few studies have done a quantitative analysis of the link between muscle deficit and ACL reconstruction retear. The objective of this study was to correlate the data of the 6-month postoperative isokinetic muscle evaluation before resuming sports activities with the occurrence of ACL reconstruction rerupture after semitendinosus short graft. The hypothesis was that patients with an ACL reconstruction retear had inferior muscle dynamometric recovery results at 6 months compared to those without this complication.

Method

Study Population

This is a retrospective cohort study. From June 2015 to December 2018, one surgeon performed ACL reconstruction with a short semitendinosus autograft for all patients who required ACL reconstruction (using TLS® (Tape locking screw) system (FH Orthopaedics, Heimsbrunn, France). All patients who had ACL reconstruction and performed isokinetic tests at their 6th postoperative month were included in this study.

The inclusion criteria were adult patient (>18 years old), who initially had an ACL tear without rupture of a peripheral plane and benefited from a primary ACL reconstruction surgery without anterolateral ligament reconstruction (ALLR) or lateral extra-articular tenodesis (LET) and who performed an isokinetic muscle test on dynamometer at the 6th postoperative month as part of the care protocol. The exclusion criteria were reconstruction for ACL reconstruction rerupture, multiligament surgery, no isokinetic assessment on dynamometer, and refusal to participate in this study. The rehabilitation protocol was standardized and given to the patient and the physiologist. Full weight bearing was immediately authorized, and the recovery of passive and active motions and passive strengthening was started the next day with the physiologist. The RTS was allowed after 6 months if the patient passed the isokinetic test with an operated/healthy knee ratio higher than 85% in flexion and extension.

Surgical Technique

The Tape Locking Screw (TLS system; FH Orthopaedics, Heimsbrunn, France) system is an ACL reconstruction method created in 2003.²³ The surgical technique consists of harvesting only one hamstring tendon (semitendinosus tendon), prepared into a short, four- to five-strand closed loop, and with a 500-N preload. According to the surgical technique, the length of the graft is correlated with the patient size. Tibial and femoral tunnels are shorter and created in a retrograde manner. Press-fit of the graft into the bone tunnels is obtained by tension on polyethylene terephthalate strips that are attached to the bone with dedicated 20-mm interference screws. Each patient was operated on with the use of a tourniquet under exclusive general anesthesia as an outpatient.

Isokinetic Test Procedure

Muscle recovery, analyzed between the healthy and operated knee, was evaluated with isokinetic tests using the CONTREX human dynamometer²⁴ by a senior re-educating physician (Fig 1). The evaluation was done systematically in extension (quadriceps muscle), as well as in flexion (hamstrings), starting with the healthy side without prior warmup. Two different speeds were

applied, one at 60°/s to obtain the muscle power curves and the other at a higher speed (180°/s) for the muscle response (or the capacity to quickly recruit muscle fibers).

Evaluation Criteria

The follow-up was prospective with the measurement of epidemiological (age, sex, weight, body mass index, and Tegner score²⁵), radiographic, and isokinetic parameters.

All of the results of the isokinetic tests on dynamometer performed at 6 months postoperatively of the ACL reconstruction were collected. At a mean of 42.3 months (minimum: 24; maximum: 63.5) of follow-up, the data were collected retrospectively. The cohort was then divided into 2 groups (Fig 2): one group without an ACL reconstruction re-rupture (Group 1) and the second group with a rerupture (Group 2). Graft failure diagnosis was initially clinical, and ACL retear was confirmed by magnetic resonance imaging (MRI). Measurement of the position of the tibial and femoral tunnels (anterior border of the exit holes) were realized in accordance with the ratio method described by Aglietti et al. by two senior surgeons.^{26,27}

Statistical Analysis

Data were collected in an Excel spreadsheet (Microsoft, Richmond, WA) and were analyzed with JMP 10.0 software (SAS, Inc.). A Shapiro-Wilk test was performed to assess the normal distribution of quantitative variables. Comparison of qualitative variables was done with a χ^2 -test. A Student's *t*-test was performed to compare quantitative variables. The significance threshold was then $P < .05$ for all tests. Mean comparative statistics between operated knee and the healthy knee were calculated for paired samples.

Results

One hundred and four (104) patients were analyzed including 11 patients (10.6%) who had an ACL reconstruction rerupture, with an average follow-up of 42.3 ± 12.1 months (minimum: 24; maximum: 63.5). Patients' characteristics, radiographic parameters, and isokinetic tests are summarized in Table 1.

Group 1 consisted of 93 patients with an average age of 26.5 ± 9.0 years old who did not have an ACL reconstruction rerupture with an average follow-up of 41.6 ± 12.1 months. Group 2 consisted of 11 patients with an average age of 22.7 ± 6.1 years old, who had an ACL reconstruction rerupture with an average follow-up of 44.8 ± 11.3 months (Table 2). The average time to rerupture after ACL reconstruction was 11.45 months (minimum: 7; maximum: 19). All of these reruptures occurred as a result of sports trauma.

No significant differences were found between the two groups concerning the age at surgery, the

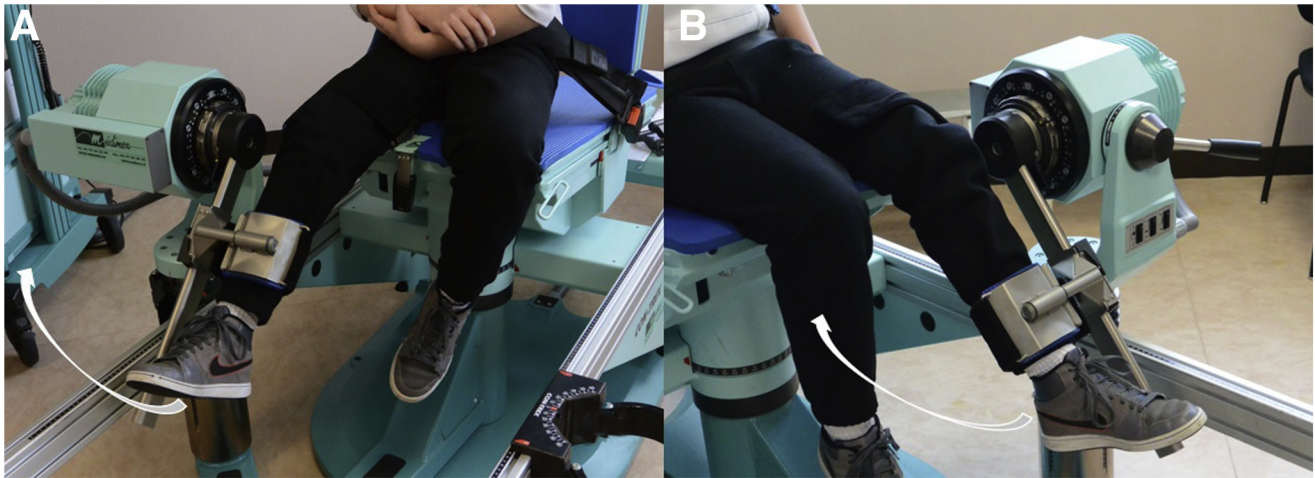


Fig 1. Isokinetic test (CONTREX dynamometer) at 6 months of anterior cruciate ligament reconstruction: example of 60°/s strength test on an operated knee (A) and response muscle test at 180°/s on a healthy knee (B).

follow-up, gender, weight, and BMI. The preoperative Tegner score was also statistically not significant between the two groups: average of 7 ± 1.1 for Group 1 and 7.3 ± 1.1 for Group 2 ($P = .56$).

Concerning extension force recovery (60°/s), the ratio between the operated and the healthy knee was $81.8\% \pm 32.0$ for the Group 1, and $53.4\% \pm 20.6$ for the Group 2 ($P = .035$). A statistically significant difference was also found ($P = .0017$) during 60°/s flexion isokinetic test between the two groups (Table 3).

The 180°/s muscle response, either on extension or flexion, showed no significant statistical difference. The values recovered were $80.4\% \pm 22.4$ versus $65.5\% \pm 19.6$ for quadriceps muscle ($P = .24$), and $92.1\% \pm 20.7$ versus $88.4\% \pm 15.5$ for hamstrings ($P = .7$).

For radiograph parameters, no statistical differences were found in terms of tibial ($P = .78$) and femoral ($P = .89$) tunnels positioning between the two groups.

Discussion

The most important finding of this study confirmed that patients with an ACL reconstruction rerupture had lower isokinetic results at 6 months compared to those without this complication in terms of muscular strength (60°/s), but not concerning the muscle response (180°/s). Isokinetic tests are commonly used during ACL reconstruction rehabilitation.^{28–30} There is only one study in the literature reporting a decrease in hamstring and quadriceps muscle strength on dynamometer (60°/s) in professional athletes with an ACL reconstruction re-tear.³¹ Although no threshold study was carried out, this series allowed a quantitative comparison of the muscular deficit on isokinetic tests prospectively before RTS.

Significant differences were found at 60°/s during extension and flexion isokinetic tests. This is in accordance with results of other studies that show an

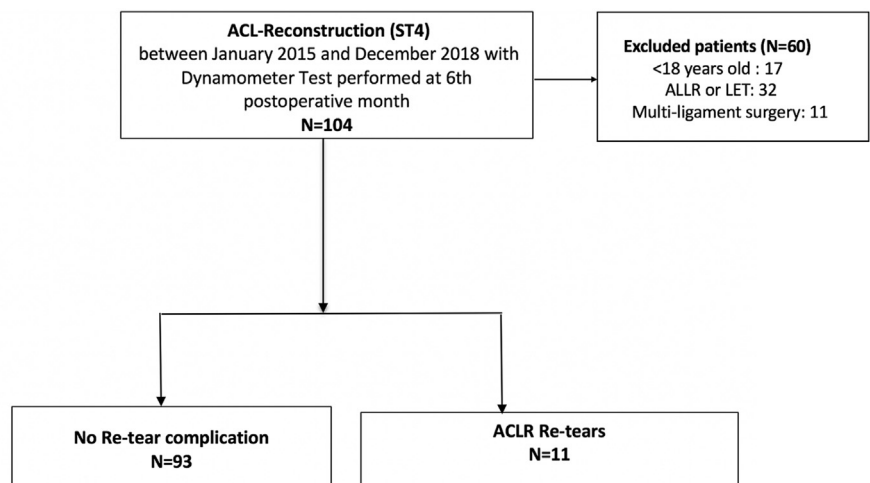


Fig 2. Study enrollment flowchart.

Table 1. Epidemiologic and Radiographic Parameters of Study Population

Parameter	Value
Number of patients	$n = 104$
Side (Right/Left)	46/56
Sex (Female/Male)	35/68
Weight (kg, median \pm SD)	73.1 ± 15.8
Size (m, median \pm SD)	$1.74 \pm .09$
BMI (median \pm SD)	23.5 ± 4.1
Follow-up (Months, median \pm SD)	42.3 ± 12.1
Preoperative Tegner Score (median \pm SD)	7.0 ± 1.1
Posterior tibial Slope (degrees, median \pm SD)	10.1 ± 3.8
HKA alignment (degrees, median \pm SD)	177.8 ± 3.3

HKA, hip-knee-ankle.

increased operated/healthy knee ratio only at this angular velocity after primary ACL reconstruction.^{32–34} Abundant data exist for these selected velocity and have been shown to highlight strength deficits. Torque output decreases as angular velocity increases above $60^\circ/s$, and the maximum torque output is shown to be between 0 and $60^\circ/s$.³⁵ For this reason, if the angular velocity that is used for strength evaluation is greater than $60^\circ/s$, strength deficiencies might not be highlighted.

Conserving the gracilis muscle would have a faster recovery time in flexion when compared to reconstruction requiring the removal of the two hamstrings.^{19–22} Although isolated sampling of semitendinosus was performed,^{36,37} isokinetic results on flexion at 6 months ($60^\circ/s$) are still insufficient.

In their systematic review of the literature, Barber-Westin et al. pointed out that RTS was based on nonspecific subjective criteria, and in the majority of cases, surgeons set the time criterion for RTS at 6 months, the theoretical date of graft healing.²⁹ Although isokinetic tests provide objective data on muscle strength recovery,³⁸ literature data do not support these tests as a reliable and reproducible predictor for RTS.^{28,39} Van Grinsven et al. suggest, however, that a threshold of 85% for the extension and the flexion must be reached before RTS.⁴⁰ In this series, the ratio between operated and healthy knee at $60^\circ/s$ was 71.6% for flexion and 53.4% for extension in Group 2. Therefore, a large majority of patients received instructions to delay their return-to-sport and to continue muscle strengthening following their isokinetic tests. For Bobkin et al.,⁴¹ patients demonstrated increasing subjective and quadriceps function when tested at later time points from surgery with a deficit muscle strength at 9 months that might improve with a 2-month rehabilitation protocol. Concerning RTS, Nagai et al.⁴² supported the continued use of isokinetic testing when examining an individual's readiness to return to sport.

Study Limitations

The main limitation of this study is its reduced size for Group 2. Indeed, the ACL reconstruction retear is a rare

event, and it would have been necessary to include a much larger number of subjects to bring more power to this prospective monitoring. Although the groups were homogeneous in terms of epidemiological data, preoperative sport level, and bone tunnel position, the low number of participants in Group 2 did not allow a multivariate analysis. Finally, no threshold study was carried out. It would be interesting to carry out a larger-scale prospective multicenter study to find the threshold from which muscle deficit would be predictive of an ACL reconstruction rerupture in case of semitendinosus reconstruction.

Conclusion

This study revealed a significant link between muscle weakness in flexion and extension during $60^\circ/s$ isokinetic test at 6 months of ACL reconstruction and ACL reconstruction rerupture after semitendinosus short autograft. Patients with an ACL reconstruction retear had inferior muscle dynamometric recovery results at 6 months before resuming sports activities.

Table 2. Patients' Characteristics and Distribution Tests (Student and χ^2) Between the Two Groups (With and Without ACL Reconstruction Rerupture)

	Without ACL Reruptures ($n = 93$)	With ACL Reruptures ($n = 11$)	<i>P</i>
Age, median \pm SD (years)	26.5 ± 9.0	22.7 ± 6.1	.53
Sex			.86
Male	62	7	
Female	31	4	
BMI median \pm SD	23.6 ± 3.8	21.3 ± 3.5	.22
Weight, median \pm SD (kg)	73.3 ± 1.6	65.7 ± 6.1	.24
Side			
Right	44	5	
Left	49	6	.51
Last follow-up, median (min; max) (months)	41.6 (24; 63.5)	44.8 (29; 54.5)	.51
Preoperative Tegner score median (min; max)	7 (4; 10)	7.3 (7; 9)	.56
Tibial slope $^\circ \pm$ SD	11.6 ± 3.6	12.1 ± 3.5	.42
HKA angle $^\circ \pm$ SD	174.4 ± 25.2	176.4 ± 4	.83
Femoral tunnel position $^\circ \pm$ SD (Aglietti Ratio method)	77.2 ± 3.6	74.3 ± 2.6	.89
Tibial tunnel position $^\circ \pm$ SD (Aglietti Ratio method)	26.1 ± 3.3	23.7 ± 1.6	.78

NOTE. Bolded values indicate significant difference ($P < .05$).

ACL, anterior cruciate ligament reconstruction; HKA, hip-knee-ankle; min, minimum; max, maximum.

Table 3. Comparison of Isokinetic Muscle Evaluation Results (60° and 180°/s) between the Two Groups (Student's *t*-Test)

Isokinetic Test	Without ACLR Retears	With ACLR Retears	<i>P</i>
	(<i>n</i> = 93)	(<i>n</i> = 11)	
60°/s Healthy knee flexion (°/s ± SD)	100.8 ± 32.0	90.8 ± 27.4	.92
60°/s Healthy knee extension (°/s ± SD)	176.8 ± 49.1	159.0 ± 40.2	.85
60°/s Operated knee flexion (°/s ± SD)	94.1 ± 32.4	66.1 ± 26.2	.0415
60°/s Operated knee extension (°/s ± SD)	137.2 ± 50.6	87.8 ± 46.6	.0225
180°/s Healthy knee flexion (°/s ± SD)	79.4 ± 27.1	71.4 ± 31.9	.91
180°/s Healthy knee extension (°/s ± SD)	133.8 ± 40.5	120.1 ± 41.5	.77
180°/s Operated knee flexion (°/s ± SD)	72.6 ± 28.4	61.2 ± 24.2	.98
180°/s Operated knee extension (°/s ± SD)	106.9 ± 40.2	79.5 ± 37.3	.79
60°/s Operated/healthy flexion ratio (% ± SD)	95.0 ± 17.5	71.6 ± 10.9	.0017
60°/s Operated/healthy extension ratio (% ± SD)	81.8 ± 32.0	53.4 ± 20.6	.035
180°/s Operated/healthy flexion ratio (% ± SD)	92.1 ± 20.7	88.4 ± 15.5	.7
180°/s Operated/healthy extension ratio (% ± SD)	80.4 ± 22.4	65.5 ± 19.6	.24

NOTE. Bolded values indicate significant difference (*P* < .05).

ACLR, anterior cruciate ligament reconstruction.

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