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ORIGINAL ARTICLE

Knee pain after anterior cruciate ligament reconstruction: evaluation of a rehabilitation protocol

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Abstract
Introduction Anterior knee pain (AKP) is a rare and difficult complication following anterior cruciate ligament (ACL) reconstruction. This disabling pain is persistent with conventional rehabilitation protocols. The aim of this work is to validate a new rehabilitation protocol that may improve the patients and allow return to daily activities including sports.
Materials and methods Forty-three patients identified with functional AKP after ACL reconstruction was enrolled in the rehabilitation protocol between 2009 and 2011. The series included twenty-six patients with hamstring grafting and seventeen patients with patellar tendon transplant. This study compares the functional outcomes and pain scores before and after the isokinetic protocol until the last follow-up at an average of 25.7 months after surgery. The evaluation was performed according to the International Knee Documentation Committee (IKDC) and included a pain assessment using the visual analog scale. Statistical analysis used Student's *t*-test for unpaired data and the Pearson correlation test for the variables. The IKDC scores were compared by the Wilcoxon test.
Results Functional outcomes and pain are significantly improved ($p < 0.0001$). The average IKDC score improved with 28 points and the pain improved with 3.2 points on the visual analog scale (VAS). The results are correlated with the follow-up time ($p = 0.008$) but not correlated with the delay between the surgery and the beginning of the isokinetic protocol.
Discussion Isokinetic rehabilitation provides a significant improvement in the knee function as measured by the IKDC score and by the VAS, regardless of the painful period preceding the program. The function improvement continues after the end of the protocol, but the pain may not completely disappear. The isokinetic rehabilitation program may resume functional AKP related to muscular deficit and may be used as the starter of other physical therapy protocols.
Level of evidence IV.

Keywords Knee surgery · Reconstruction · IKDC score · Anterior cruciate ligament · Hamstring · Patellar tendon · Rehabilitation · Isokinetic · Muscular defect · Anterior knee pain · ACL reconstruction

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Introduction

The anterior knee pain after reconstruction of the anterior cruciate ligament (ACL) has different origins [1, 2]. Morbidity at the donor site is the main cause of pain with rates ranging from 11.5 prior to 22 % depending on the registry used [1, 3]. This pain can be associated with a deficit of the quadriceps muscle wherever the graft was harvested [4, 5]. Series assessing the strength of the extension at 6 months following ligamentoplasty show an average difference from 10 to 30 % in the maximum strength between the two quadriceps (N/m) [6–10]. While in most cases, the deficit of the quadriceps is asymptomatic [7, 8], it can induce a typical patellar syndrome with painful knee when walking down the stairs [11]. This pain is different from the graft

harvesting at the donor site and is not related to an objective lesion. This type of pain is considered functional by analogy with the idiopathic patellofemoral syndrome [12, 13].

Patellofemoral pain following ACL reconstruction is estimated at 5 % [14]. The origin of the pain is unclear, and the causal mechanism or injury is not identified. The series that evaluate the condition of the cartilage after tearing and/or ACL reconstruction showed that patellofemoral cartilage lesions are common, uncorrelated with painful symptoms [15, 16]. Functional role in the anterior pain therefore appears difficult to evaluate. This explains why the literature is poor on the subject, while the symptoms can be debilitating and difficult to support the treatment plan.

This type of pain requires specific rehabilitation support because some exercises, including those in open kinetic chain, overload the patellofemoral joint and may induce a patellar syndrome [17]. The isokinetic rehabilitation protocols can be adapted to obtain painless strengthening of the quadriceps [18]. Isokinetic rehabilitation has shown efficacy in the treatment for idiopathic patellofemoral syndrome [19, 20]. In ligament pathology, isokinetic exercises were used primarily as a tool for evaluation of muscle deficits [4–10, 21–24] but only recently as a tool for rehabilitation.

The goal of the study is to assess the efficacy of the isokinetic rehabilitation in the management of functional anterior knee pain after ACL reconstruction.

Materials and methods

This is a retrospective study on a patient cohort from one medical institution. The series is not randomized nor controlled, but it included only patients with disabilitating postoperative anterior pain in the knee and having an isokinetic rehabilitation protocol after ACL reconstruction. The isokinetic rehabilitation protocol was a second-line protocol after failure of the conventional physiotherapy. The pain was awakened by the patellofemoral overload when walking down the stairs or during prolonged flexion positions.

Over the period 2009–2011, two thousand and twenty-six ligamentoplasties involving the ACL were performed in our center by three operators. The series included one thousand and 42 patellar tendon grafts, eight hundred and ninety-three hamstring grafts, and ninety-one quadriceps tendon grafts. Eighty-three patients representing 4 % were followed with a specific isokinetic rehabilitation protocol including 40 hamstring, 37 patellar tendons, and four quadricipital tendons.

We excluded revision surgery of whatever cause (2 patients for iterative ACL tear, 4 patients for meniscus tear, and 10 patients for the cyclops syndrome) and cases with the delay exceeding 18 months between surgery and the start of the protocol (13 patients) as well as the cases with a follow-up inferior to 6 months (3 patients). We arbitrarily set at 15 % the minimum difference between the maximum moment of force (N/m) of the quadriceps of the operated leg and that of the non-operated leg. The patients with a lower differential were excluded from the analysis (8 patients).

There is no validated protocol of isokinetic rehabilitation in the literature for strengthening the quadriceps after ACL reconstruction. The protocol used in this study was developed by the physical therapist of the center (D. Monnot). The isokinetic sessions were performed on an isokinetic dynamometer CON-TREX MG (Con-Trex AG, Dübendorf, Switzerland) (Fig. 1). For the installation on the dynamometer, the subject was sitting on the seat with the backrest tilted back making an angle from 15° from vertical (Fig. 2). The webbing of the trunk and pelvis was performed by two belt and a velcro strap. The member tested was secured with a strap at the level of the thigh, and the opposite side was free. The selection of different speeds in concentric and eccentric fashion and the programming for the ranges of motion complied with the recommendations issued by Crosier on the proper use of the isokinetic device [25]. During the tests, the subjects were asked to produce their maximum force throughout the range of motion and the examiner verbally encouraged the subject in different series. Before the first session, the moments of maximum strength of the quadriceps (MSmaxQ) (N/m) were determined for the operated and the non-operated legs at different speeds (Table 1). The dynamometer schedule rehabilitation itself was carried out according to the balance sheet (Table 2).

The rehabilitation protocol consisted of two sessions per week. Each session lasted 25 min on average, always started with 5 min of warm-up on a cycle ergometer, and ended with a self-stretching of the different sub-pelvic muscle chains. Between isokinetic sessions, painless soft classical therapy was continued.

Patients were all reviewed in 2012. Functional assessment was performed using the International Knee Documentation Committee (IKDC) subjective score and visual analogue scale (VAS), or during a telephone conversation, or by sending questionnaires by email or post.

Statistical analysis was performed by means of Student's *t*-test for unpaired data. The IKDC scores were compared by the Wilcoxon test. The distribution of quantitative variables was assessed by Pearson correlation test. Differences were considered statistically significant when the risk of a type I error was <5 %. The calculations were performed using the free statistical software R published under the GNU-GPL.

Fig. 1 Isokinetic dynamometer CON-TREX MG (Con-Trex AG, Dübendorf, Switzerland)

Fig. 2 Installation of the patient on the dynamometer

Results

The cohort included 23 women and 20 men with an average age at surgery of 35 ± 8.17 years. The tissues used for reconstruction included 26 hamstrings and 17 patellar tendons. Thirty-nine out of the forty-three patients were reviewed, three cases were lost of view, and one patient refused to participate in the study. The operative reports described the appearance of the patellofemoral cartilage that was macroscopically intact in 81 % of cases. At the initial assessment, the average isokinetic quadriceps deficit compared to the contralateral leg was 43.67 ± 19.5 % in concentric and 32.12 ± 19.3 % in eccentric load. Figures 3 and 4 show the curves obtained for the quadriceps at the initial assessment of a patient. The average time frame between surgery and the isokinetic rehabilitation was 8.5 ± 3.2 months. The average follow-up time was 25.7 ± 9.7 months as compared to the time of the surgery and 17.4 ± 9.06 months from the beginning of the protocol.

Table 1 Initial assessment of MSmaxQ from the operated and the non-operated legs to different speeds (break of 60 s between each sets)

	Concentric			Eccentric
Training	4 reps to 180°/s	3 reps to 90°/s	4 reps to 240°/s	3 reps to 30°/s
Measures	6 reps to 180°/s	5 reps to 90°/s	20 reps to 240°/s	5 reps to 180°/s

The average gain between the beginning and end of isokinetic protocol of rehabilitation was of 28 points for the IKDC ($p < 0.0001$) and of 2.3 points for the VAS ($p < 0.0001$). The average gain was of 9 points for the IKDC ($p < 0.0001$) and of 1.4 points for the VAS ($p < 0.0001$). Figures 5 and 6 show the box plots of IKDC and VAS.

International Knee Documentation Committee's scores at follow-up were weakly correlated with the duration of follow-up ($p = 0.008$) (Fig. 7), but not correlated with the delay between surgery and implementation of the protocol ($p = 0.54$). The subgroup analysis for gender and the type of transplant is displayed in Table 3. Statistical analysis shows that at the time of surgery, the gender and the type of transplant had no impact on functional outcomes as assessed by the IKDC and the VAS.

Discussion

Isokinetic rehabilitation allows regression of the painful symptoms and improves the subjective IKDC score in the functional anterior knee pain after ACL reconstruction. To our knowledge, this is the first study evaluating the protocol of isokinetic exercises with strengthening of the quadriceps after ACL reconstruction in a hyperalgesic context.

The analysis of the literature shows that the quadriceps weakness is a risk factor for anterior knee pain [4, 5] that strengthening of the quadriceps is associated with a

Table 2 D. Monnot isokinetic rehabilitation protocol for knee pain after anterior cruciate ligament reconstruction (break of 15 s between each sets)

	Concentric exercises	Eccentric exercises
1st session	3 sets of 6 reps at 75 % MSmaxQ (Sp1 450°/s, Sp2 400°/s, Sp3 350°/s) 4 sets of 4 reps at 75 % MSmaxQ (Sp1 300°/s, Sp2 300°/s, Sp3 270°/s, Sp4 270°/s)	3 sets of 4 reps at 75 % MSmaxQ (Sp1 15°/s, Sp2 15°/s, Sp3 15°/s)
2nd session	3 sets of 6 reps at 75 % MSmaxQ (Sp1 400°/s, Sp2 350°/s, Sp3 350°/s) 4 sets of 4 reps at 75 % MSmaxQ (Sp1 300°/s, Sp2 270°/s, Sp3 240°/s, Sp4 240°/s)	2 sets of 4 reps at 75 % MSmaxQ (Sp1 15°/s, Sp2 30°/s)
3rd session	4 sets of 4 reps at 75 % MSmaxQ (Sp1 240°/s, Sp2 240°/s, Sp3 240°/s, Sp4 240°/s)	3 sets of 4 reps at 75 % MSmaxQ (Sp1 30°/s, Sp2 30°/s, Sp3 30°/s)
Following sessions	4 sets of 4 reps at 75 % MSmaxQ by gradually reducing speed to 210°/s, 180°/s, 150°/s	3 sets of 4 reps at 75 % MSmaxQ (Sp1 30°/s, Sp2 30°/s, Sp3 30°/s)

Sp: speed, MSmaxQ: moment of maximum strength of the quadriceps (N/m)

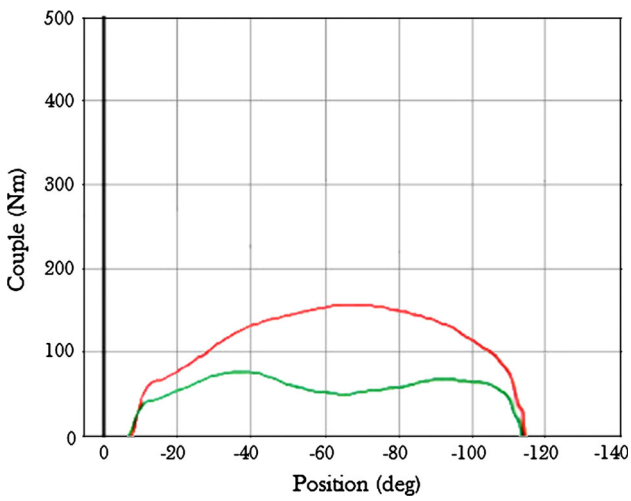

Fig. 3 Concentric assessment of the quadriceps (*red curve* non-operated side, *green curve* operated side) (color figure online)

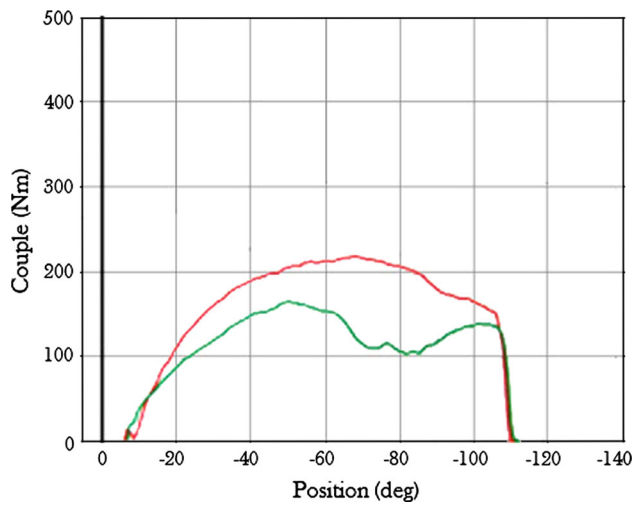

Fig. 4 Eccentric assessment of the quadriceps (*red curve* non-operated side, *green curve* operated side) (color figure online)

regression of the pain [26] and that pain hinders the recovery of the quadriceps [7]. The relationship between the dysfunction of the quadriceps and the occurrence of the patellofemoral pain is numerous [27]. The muscle dysfunction after ACL reconstruction is fundamentally different from that observed in the idiopathic patellofemoral syndrome. After ACL rupture, some complex neurophysiological processes limiting the anterior tibial translation are activated. They may include muscle reflex arcs of inhibition [28] or co-hamstring–quadriceps contraction [29]. Other causes of anterior knee pain may act as irritating triggers at the origin of a functional limitations [13]. Thus, neuropathic pain secondary to bone or levy syndromes cyclops, or meniscal lesions are at risk of inducing or aggravating the quadriceps muscle weakness due to under-utilization of the member. The recovery of the quadriceps is usually limited in time due to the spontaneous favorable evolution of most of these situations [1]. This explains probably the absence of series analyzing functional pain that seems destined to decline with the recovery of quadriceps deficit. It is in this context that we recommend the use of a program of isokinetic exercises with setting options that control the speed of work in predetermined angular sectors. In our series of ACL reconstruction, significant improvements in functional outcome and pain suggest that isokinetic quadriceps muscle strengthening may be used in cases showing with hyperalgesia. This goes back to what Hazneci [19] and Alaca [20] showed about muscular deficits in the idiopathic patellofemoral syndrome.

Analysis of functional results in our series shows that the improvement continues significantly after the isokinetic protocol, while the quadriceps recovers a normal level. This improvement in two phases suggests that the recovery of the quadriceps muscle is only one element of the painful

symptoms. It may be the isokinetic rehabilitation that enhances the ability to seek quadriceps infra-painful areas [18], breaking the vicious circle of "muscle pain deficit." The significant positive correlation between the results at the last follow and the postoperative delay suggests that the natural history of functional anterior knee pain after ACL reconstruction depends on other factors besides the quadriceps. We therefore advocate to accompany the functional recovery with running, exercise, proprioception training, and musculation for stimulating the resume of daily activities that are essential for the recovery of painless patellofemoral kinematics.

In our series, the hamstrings were harvested in 60 % of cases. The quadriceps weakness is not the result of a direct lesion of the extensor mechanism as is observed in the donor site [6]. In the future, a better understanding of the pathophysiology of the muscle dysfunction after ACL reconstruction could redefine the objectives of the isokinetic rehabilitation such as restoring an agonist/antagonist ratio (quadriceps/hamstrings) similar to the healthy limb and maybe allow a faster functional recovery.

There is no current certitude about the minimum time when histological maturation of the graft allows the practice of isokinetic exercises in a repaired ACL. The isokinetic rehabilitation is a model of exercise in open kinetic chain. The principle of exercise in open chain after ACL reconstruction is analyzed in the literature [30], but this model presents a theoretical risk of graft failure [31]. Based on the work of Amiel et al. [32], we remain cautious and do not recommend the use of isokinetic exercise before 4.5 months after surgery.

In our series, there is no significant difference between the functional outcome and the timing of the rehabilitation. Thus, the delay of the specific support by the isokinetic quadriceps muscle weakness does not seem to be detrimental to the anterior knee. This rehabilitation protocol

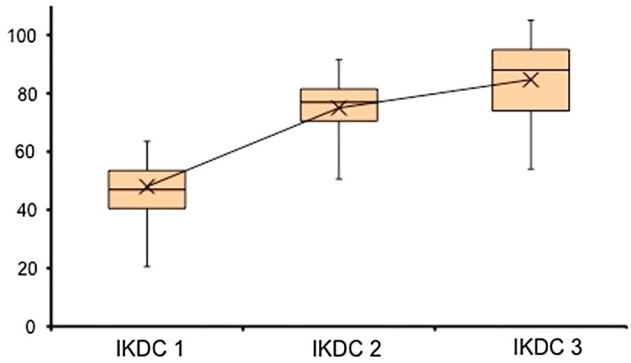

Fig. 5 *Box plots* of IKDC (IKDC 1: score at the beginning of isokinetic protocol, IKDC 2: score at the end of isokinetic protocol, IKDC 3: score at the last follow-up)

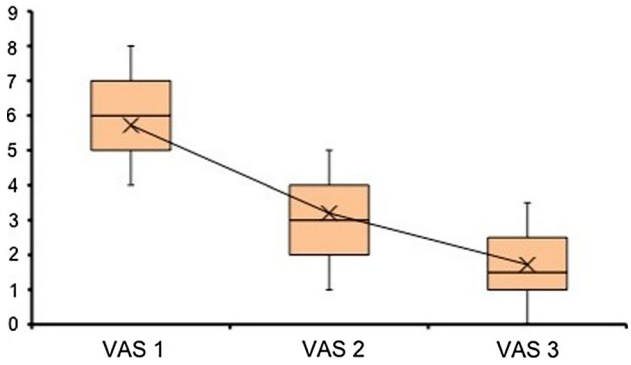

Fig. 6 *Box plots* of VAS (VAS 1: score at the beginning of isokinetic protocol, VAS 2: score at the end of isokinetic protocol, VAS 3: score at the last follow-up)

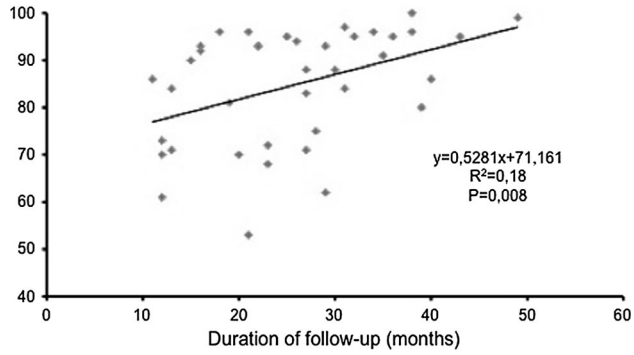

Fig. 7 International Knee Documentation Committee according to the duration of follow-up (Pearson correlation test)

Table 3 Subgroup analysis according to gender and the type of transplant

	IKDC		VAS	
	Before Iso	Last FU	Before Iso	Last FU
Genre				
Male	51 ± 10.6	82.5 ± 13.9	5.8 ± 11.4	2.25 ± 1.74
Female	43.9 ± 13.7	85.4 ± 11.2	5.5 ± 9.3	1.64 ± 1.25
Transplant				
Patellar tendon	43.5 ± 10.6	84 ± 11.05	6.15 ± 11.1	1.8 ± 1.2
Hamstrings	52 ± 14.1	84.4 ± 14.5	4.9 ± 9.6	2.05 ± 1.9

±: standard deviation, before Iso: score at the beginning of isokinetic protocol, last FU: last follow-up

appears to have similar efficacy regardless of the duration of the previous pain.

This study is retrospective, and the evaluation of the results is related to the patient's subjective report. As this is a single group cohort, there is no control population treated by traditional rehabilitation. However, the population included a large group of functional anterior pain treated by isokinetic exercises. The proportion of patients with anterior functional pain after ACL reconstruction represents an average of 4 % that is similar to other studies (Aglietti) [14]. This proportion may be undervalued because only the patients with isokinetic rehabilitation performed in our center were included.

Conclusion

Our study shows that the isokinetic rehabilitation is accompanied by a decrease in anterior knee pain after ACL reconstruction. Our protocol is simple, reliable, and reproducible suitable for an outpatient basis in every physiotherapy consulting rooms having an isokinetic device with a rotary motion. However, this protocol does not allow the complete regression of the functional discomfort. Further improved outcomes with reduced pain were found at long term after the end of the rehabilitation protocol. The natural history of the anterior knee pain after ACL reconstruction remains unclear and may be related to the quadriceps muscle weakness that has yet to be clarified. Isokinetic rehabilitation nevertheless appears to be a useful tool in the management of anterior knee pain after ACL reconstruction in cases of therapeutic impasse with classical rehabilitation techniques.

Conflict of interest Francois Gadea receives a grant from Arthrex Inc, Amplitude Inc and Depuy Inc. Mathie Thaunat receives a grant from Arthrex Inc, Amplitude Inc and Depuy Inc. Jean-Marie Fayard receives personal fees from Arthrex Inc, Amplitude Inc and Depuy Inc. Bertrand Sonnery-Cottet receives personal fees from Arthrex Inc, Amplitude Inc and Depuy Inc.

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