

# Early and Intensive Physiotherapy Accelerates Recovery Postarthroscopic Meniscectomy: Results of a Randomized Controlled Study

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**ABSTRACT.** Moffet H, Richards CL, Malouin F, Bravo G, Paradis G. Early and intensive physiotherapy accelerates recovery postarthroscopic meniscectomy: results of a randomized controlled study. *Arch Phys Med Rehabil* 1994;75:415-26.

• The efficacy of an early, intensive, supervised rehabilitation program to accelerate knee strength recovery in the first 3 weeks postmeniscectomy by arthroscopy was evaluated using a randomized controlled trial design. The maximal voluntary isokinetic strength of 31 men, randomly allocated to either a treatment (EXP) or a control (CTL) group, was measured twice by a blind rater: preoperatively (pretest) and 3 weeks postsurgery (posttest), using a computer-controlled Kin-Com dynamometer (Chattecx Corporation, Chattanooga, TN). Strength deficits of the operated leg at the pretest and posttest were established in percent of the values obtained for the sound leg at the pretest. In the interval between the surgery and the posttest, the patients of the EXP group ( $n = 15$ ) received nine supervised treatments combined to home exercises whereas patients of the control group ( $n = 16$ ) had no specific physiotherapy treatment but were given instructions in postsurgical management and prescribed exercises by the orthopedic surgeons. Patients of the EXP group had better knee extensor strength recovery than patients of the CTL group (ANCOVA,  $p < 0.001$ ). The size of the strength difference (3 weeks postsurgery) between EXP and CTL subgroups ( $n = 8$ ) matched according to preoperative deficits was as large as 26% and the residual deficits of the untreated patients were two to three times larger than those of the treated patients. The results of this study highlight the importance of instituting an early intensive and supervised rehabilitation program, especially for workers returning to a strenuous job requiring good knee extensor muscle function.

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Supervised rehabilitation after arthroscopic meniscectomy is frequently considered by orthopedic surgeons and physiotherapists as nonessential because patients rapidly regain their functional autonomy without specific postoperative treatment. This lack of emphasis on postoperative rehabilitation is understandable because patients who undergo arthroscopic meniscectomy are, in general, operated as outpatients, have only light postoperative knee pain and effusion, take little or no medication, and rarely develop postoperative complications.<sup>1-12</sup> Usually they can walk without assistive devices within 1 week and return to work after a few days to 6 weeks,<sup>1-7,9,11,13-18</sup> depending on the physical requirements of their jobs.<sup>1,14,16-18</sup> Finally, a large proportion of patients progressively resume recreational and sport activities although only 29% to 62% return to the same sport without limitations or symptoms.<sup>3,4,17</sup>

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Quantitative evaluations of knee function after arthroscopic meniscectomy have, however, clearly shown that recovery is still incomplete 4 to 8 weeks postsurgery, when the majority of the patients have resumed work. Indeed, abnormalities in leg movements and muscle activations during submaximal locomotor activities such as gait, stair climbing, and descending have been observed up to 4 weeks postmeniscectomy.<sup>19</sup> At 8 weeks postsurgery, even though movements and knee extensor muscle activations are similar to normal values, patients still walk and descend stairs slower suggesting that total locomotor recovery is not attained.<sup>19</sup> Furthermore, strength evaluations have revealed residual deficits in the knee extensor muscles as large as 20% to 40%<sup>3,5,7,20</sup> and up to 20% in the knee flexor muscles<sup>3</sup> 3 weeks postmeniscectomy. In addition, flap meniscal lesions appear to predispose to larger extensor strength deficits than other types of meniscal lesions.<sup>3</sup> Because a 10% residual strength deficit of the knee extensor and flexor muscles has been associated to a higher frequency of knee injury,<sup>21</sup> it is likely that patients after meniscectomy, in particular those with flap tears, are exposed to a higher risk of reinjury, especially when they return to a physically demanding job. These new findings on the early recovery of motor function postarthroscopic meniscectomy highlight the need for a rehabilitation program to promote a faster recovery in the first month postsurgery.

The efficacy of such a rehabilitation program, however, has not been demonstrated in a randomized controlled trial (RCT). Previous studies have rather correlated retrospectively different rehabilitation methods with long-term post-

surgical success<sup>22</sup> or compared different postoperative managements such as home exercises versus a supervised rehabilitation program without a control group.<sup>23</sup> Others have suggested specific training protocols to improve muscle strength<sup>2,24-29</sup> or have tested the efficacy of isolated modalities such as transcutaneous electrical nerve stimulation.<sup>10</sup> Although consensus has not been reached on the definition of an optimal postoperative knee rehabilitation program, general rehabilitation principles support an early and intensive intervention.<sup>26,30,31</sup>

The main purpose of this study is, therefore, to evaluate the effects of a new, early and specially adapted physiotherapy (PT) treatment program, on the magnitude of knee strength deficits 3 weeks postarthroscopic meniscectomy using an RCT design. A secondary aim is to verify if patients with flap and bucket-handle tears both gain benefit from the therapy. The main research hypothesis is that the treated patients, irrespective of the type of meniscal lesion, will have smaller knee strength deficits than the untreated patients 3 weeks postsurgery. These differences in strength deficits should also be reflected in the scores of knee function obtained with the Lysholm and Gillquist's questionnaire.<sup>32</sup> Finally, patient compliance to the PT program and the evolution of clinical signs and symptoms during the treatment period will be outlined.

## SUBJECTS AND EXPERIMENTAL DESIGN

The patients included in the RCT were selected from the surgical lists of seven orthopedic surgeons in four hospitals according to the following criteria: men, aged between 20 to 55 years, scheduled for a partial medial meniscectomy by arthroscopy, without previous knee surgery, knee ligament instability, neuromuscular or rheumatological disorders. From September 1988 to July 1991, 94 men met these criteria but only 56 (60%) volunteered for the study. They gave their informed consent and then, were evaluated before the surgery in a single testing session, the pretest. Acceptance of the patients in the study was, however, contingent upon the confirmation by the orthopedic surgeon that an isolated partial medial meniscectomy by arthroscopy was performed without complications. Only 35 men had the expected surgical intervention and they were randomly allocated on the day of the surgery to either a treatment (EXP) or a control (CTL) group after stratification for the type of meniscal lesion (B: bucket-handle and F: flap tears). Because four patients withdrew from the study in the postoperative period, 31 patients were reevaluated postoperatively (posttest and follow-up) and completed all steps of the study. The CTL group ( $n = 16$ ) was composed of 5 patients with B and 11 patients with F tears and the EXP group ( $n = 15$ ) of 5 patients with B and 10 patients with F tears. Table 1 presents selected anthropometric and clinical findings, and gives information about duration of symptoms, the surgery, the testing sessions, and follow-up.

## Experimental Evaluations

The patients participated in two testing sessions: a pretest (mean =  $5 \pm 6$  days; median = 4 days presurgery) and a

posttest (mean =  $24 \pm 2$  days; median = 23 days postmeniscectomy). During these sessions, knee function was evaluated by means of clinical measures (range of knee motion, thigh atrophy, knee effusion, and pain), isokinetic (ISOK) strength measures, and with the Lysholm and Gillquist questionnaire.<sup>32</sup> In addition, 3 months (follow-up 1) and 6 months (follow-up 2) postsurgery, the patients were rescored on the Lysholm and Gillquist questionnaire. All the evaluations were performed by the same rater, a physiotherapist, unaware of group assignments (blind rater).

At the beginning of each testing session, ligament stability (valgus and varus stresses, Lachman and anterior drawer test) and patellar integrity (Clarke's sign, compression, mobility) were evaluated by specific clinical tests<sup>33,34</sup> to exclude major ligamentous or patellar problems. Then, clinical measures were recorded: the passive range of motion in flexion and extension of both knees was monitored with a goniometer, the circumference of the thighs was measured with a tape measure placed 20cm above the lateral knee joint line, and the presence or absence of effusion was estimated with the patellar tap test and the brush test.<sup>34</sup>

Thereafter, the maximal voluntary ISOK strength of the knee extensor and flexor muscles was measured at  $30^\circ$  and  $180^\circ/\text{sec}$ , using a computer-controlled Kin-Com dynamometer.<sup>8</sup> Both legs were evaluated (the sound leg was always evaluated first) at the pretest whereas only the operated leg was retested at the posttest. Each of the 4 ISOK tests (extension and flexion at  $30^\circ$  and  $180^\circ/\text{sec}$ ) consisted of three maximal voluntary contractions (MVCs) through an arc of  $90^\circ$  (full extension corresponding to  $0^\circ$  to/from  $90^\circ$  of flexion) interspersed by a 1 minute rest period. A 2-minute rest interval was given between tests. A maximal static contraction of 2 seconds preceded each dynamic contraction, to minimize the effect of force development on the dynamic strength record.<sup>18,35</sup> The order of the 4 ISOK tests was randomly determined for each patient and then, this order was repeated for both legs at the pretest and the operated leg at the posttest. Before the tests, the patients performed 10 consecutive submaximal flexion-extension contractions (warm-up period) at  $60^\circ/\text{sec}$  to minimize risk of injury and to provide a familiarization period with the testing system. All patients received the same instructions and were encouraged verbally to give their maximal effort during tests. The severity of pain was monitored immediately after each MVC trial with the present *pain index scale*: PPI, 0-5 introduced by Melzack.<sup>36</sup> During the pretest, only one patient (in the EXP-F subgroup) could not perform the extension test at  $180^\circ/\text{sec}$  because of intense pain.

General knee function at the pretest and posttest, and at the 3 and 6 month follow-up evaluations was evaluated with a knee scoring-scale adapted from the Lysholm and Gillquist questionnaire.<sup>32</sup> This questionnaire includes 8 different sections evaluating knee function: limp (5 points), weight support (5), stairclimbing (10), squatting (5), giving way (30), and pain (30) during walking, running and jumping, effusion (10), and thigh atrophy (5). The sole modification made was the addition of a level (constant and slight = 20 points) in the pain section without modifying its total point value of

30. This change was guided by previous use of the questionnaire with patients having meniscal lesions. A maximum score of 100 points corresponded to normal knee function.<sup>32</sup>

### Postoperative Management

**Experimental group.** The early and intense physiotherapy (PT) program combined a standardized home exercise program that began on the day of the surgery with a series of nine supervised PT treatments provided at the hospital in the 3 weeks following the meniscectomy. In each of the four hospital centers where patients had surgery, two physiotherapists were specially trained to teach the first section of the home exercise program about 3 hours following the meniscectomy. All patients were required to attend 9 PT treatments in the Physiotherapy Department of one hospital, where the same two physiotherapists gave the treatments. These physiotherapists also verified and progressively adapted the home exercises that were to be performed each day that the patients did not attend supervised PT treatments at the hospital, to insure optimal intensity of the home exercises all along the treatment period.

The home exercise program included two main sections. The first section concerned specific instructions and the exercises prescribed for the first week postsurgery whereas the second section covered the second and third weeks postmeniscectomy. These home exercises were (1) rapid alternated ankle movements to help prevent circulatory complications (10 repetitions (rep) every 2 hours for a minimum of 50 rep per day), (2) active self-assisted knee mobility exercises (5 rep of maximal knee flexion and extension each 2 hours during the morning and afternoon for a total of 25 to 30 rep), (3) isometric (ISOM) contractions of the quadriceps with the knee extended (0° of flexion) and then flexed at about 20°, and (4) straight leg raises. The latter three strengthening exercises were performed twice a day and were progressed so that after 7 days (1) 10 MVCs were sustained for 10 seconds and interspersed by 30 seconds of rest and, (2) 30 MVCs were sustained for 5 seconds and interspersed by 5 seconds of rest. The patients were told that the exercises should be relatively pain free (not exacerbating pain). Moreover, a booklet given to the patients contained specific instructions about the use of crutches (progressive weight bearing), ice applications (2 to 3 times per day for 15 minutes each time), limb elevation and compressive bandage. The second section of the home exercise program was concerned mainly with the progressive addition of weights (by 1 pound increments) when performing the strengthening exercises of the quadriceps: isotonic quadriceps contractions from about 30° to 0° and straight-leg-raising exercises. The active self-assisted knee mobility exercises were continued whereas ice applications after exercises were recommended only if needed. Finally, instructions were outlined and each exercise was illustrated in the booklet. Patient compliance to the home exercises and individual progress was recorded by means of a logbook kept by the patients.

The supervised PT program was initiated as early as the second or third day ( $2.5 \pm 0.9$  days) postsurgery and consisted of nine treatments (treatment 1: T1 to treatment 9: T9): three treatments per week for the 3 weeks following

the surgery (table 2). In general, only 2 days (mean  $2.3 \pm 1.2$  days) interspaced two consecutive treatments and the last treatment was given  $21.3 \pm 1.6$  days postsurgery. At each PT treatment, the patients were supervised and knee joint responses (range of motion, pain, effusion) were monitored to optimize the effects of the PT treatments and to minimize the possibility of knee joint irritation. The goals of these treatments were to reduce knee pain and effusion, regain knee mobility, and strengthen the knee extensor and flexor muscles. In the initial rehabilitation phase, ie, in the first week postsurgery (T1 to T3), attention was given to the reduction of postoperative pain and effusion to promote, as soon as possible, better knee mobility and muscle control. Thus, modalities such as transcutaneous electrical nerve stimulation (TENS), ice applications, and a compressive bandage were used in conjunction with knee mobility exercises (performed in the pain-free range of motion) and multiple angle-specific ISOM exercises for the knee flexor and extensor muscles. The ISOM exercises were performed at multiple angles because strength gains are known to be specific to the trained positions<sup>37,38</sup> and they were performed at 30° and 60° of flexion because less muscle inhibition occurs with the knee flexed.<sup>39,40</sup>

The second phase of rehabilitation (T4 to T9) included dynamic exercises to increase muscle strength and endurance (ISOK exercises and bicycle ergometer) and began about 10 days postsurgery, when the patients were less aware of the need to protect the knee and there was less pain and effusion. The ISOK strengthening exercises were performed on a Cybex II dynamometer<sup>b</sup> at three different velocities because strength gains are known to be speed-specific.<sup>37,41-43</sup> The exercises were first performed at 60° and 120°/sec (second week: T4 to T6) and then at a higher speed (200°/sec) in the last week (T7 to T9) of training. Low velocities of training (under 60°/sec) were not used to avoid higher compressive forces that could irritate the healing knee joint.<sup>25,30</sup> The ISOK exercises were progressed from one to three sets of 10 maximal alternated flexion and extension contractions in the full available range of knee motion. Bicycle ergometry began, as for the ISOK exercises, at T4 ( $9.7 \pm 1.1$  days postsurgery) and the duration of the exercises was gradually increased from 5 to 30 minutes. More details about the supervised PT program are shown in table 2.

**Control group.** In contrast, patients of the CTL group had no supervised PT treatments. They were, however, given instructions about the use of crutches, the compressive bandage, and the use of ice to reduce the immediate postoperative knee pain and effusion. In addition, home exercises prescribed by the orthopedic surgeons (ISOM contractions of the quadriceps and/or straight-leg-raising exercises) were taught to the patients by a nurse the day of the surgery, as was the usual practice.

### DATA ANALYSIS

The extent of the movement limitations and thigh atrophy at the pretest and posttest was determined by calculating the difference between the sound and the injured legs for the amplitude of passive knee flexion and extension and the

circumference of the thigh. Knee effusion was judged present or absent from the clinical tests.

Force, angle, and angular velocity signals from the Kin-Com dynamometer were recorded at a sampling frequency of 400Hz and fed to an IBM AT computer.<sup>c</sup> The forces measured during the ISOK tests were corrected for passive forces due to limb weight and the lever arm.<sup>18,44</sup> For each patient and each ISOK test, the best MVC trial, as determined by the magnitude of the area under the moment of force-angle curve, was retained for analysis. Specific areas under segments of the moment-angle curves that corresponded to constant velocity phases of the movement<sup>18,35,45</sup> were then calculated. For the flexion tests, the segment ranged between 20° and 80° and for the extension tests, it ranged from 10° to 70°, except in one patient with a flexion contracture of 10°. In the remainder of this text, the variable "area under the moment of force-angle curve" is referred to as "work." For each patient, work deficits of the injured leg at the pretest and posttest were established as a percent of the values obtained for the sound leg at the pretest. Work deficit values for both groups (EXP and CTL) and subgroups of patients with bucket-handle (B) or flap (F) tears (EXP-B, EXP-F, CTL-B and CTL-F) were then expressed as a mean percent  $\pm$  1SD in bar graphs (figs 1-3).

### STATISTICAL ANALYSIS

The anthropometric data (age, weight, and height), the duration of symptoms before surgery, the duration of surgery and tourniquet time, and the intervals between surgery and the evaluations (pretest and posttest, follow-up 1 and 2) were compared between patients of the CTL and EXP groups (F + B, F, B) using independent Student *t* tests (table 1). The level of significance was set at  $\alpha = 0.05$ .

The significance of the effect of treatment (group effect) on the magnitude of the postoperative work deficits was tested with an analysis of covariance (ANCOVA,  $p < 0.05$ ) in the 31 patients. This statistical analysis provided a method to adjust for preexisting differences in the preoperative work deficits among groups, and thereby increased the precision of the analysis by removing bias due to the groups not being perfectly matched. Thereafter, the effect of treatment was reexamined (ANCOVA) in eight patients of the CTL group and eight patients of the EXP group matched by the magnitude of their preoperative extension work deficits ( $\pm 4\%$  of extension work deficit at 30°/sec; range 0.4 to 3.6%) and their type of meniscal lesion. It was only possible to match eight pairs of patients with these criteria. These patients were chosen without knowing the magnitude of their postoperative work deficits. Lastly, the significance of the effect of treatment (ANCOVA) was tested separately for each of the two types of meniscal lesions: bucket-handle (B) and flap (F). All the analyses were done after verifying that the variables were normally distributed in the groups compared. Power analyses were done for all nonsignificant results.<sup>46</sup> The difference between groups ( $\delta$ ) judged as clinically important was fixed at 50% of the mean residual postoperative deficit without treatment.

The effect of treatment on four clinical factors—pain during ISOK tests, knee effusion, thigh atrophy, and movement

limitations—was verified with Fisher's exact test. At first, the difference between groups (EXP and CTL) was tested for the presence or absence of these negative clinical factors (two categories) at the posttest. Secondly, the patients were classified into three categories according to changes observed between the pretest and the posttest for the severity of pain, presence of effusion, amount of thigh atrophy, and degree of knee movement limitation. These categories were (1) improvement from pretest to posttest, (2) no change, and (3) deterioration.

The functional knee scores obtained from the Lysholm and Gillquist questionnaire<sup>32</sup> were analyzed by means of a two-way analysis of variance for repeated measures (MANOVA) to determine the effects of group (CTL and EXP;  $n = 31$  or  $n = 16$  matched-patients), time (two testing sessions: pretest and posttest; and two follow-up evaluations: 3 and 6 months postmeniscectomy) and the group by time interaction. An analysis of covariance was also used to evaluate the effect of treatment (group effect) on the posttest scores in regard to the scores obtained at the pretest. Finally, the relationship between the magnitude of work deficits at each testing session (pretest and posttest) and the corresponding functional knee scores was evaluated by Pearson correlation coefficients.

### RESULTS

#### Patient Characteristics

The age, weight, and height of the patients in both groups (CTL and EXP) and subgroups (CTL-F and EXP-F; CTL-B and EXP-B) were comparable (table 1). Similarities between groups were also found for the side of the injured knee (right/left: CTL, 9/7; EXP, 7/8), mechanism of injury (sudden/insidious onset: CTL, 10/6; EXP, 10/5) and prevalence of osteo-articular degenerative changes of the femoral condyles and/or tibial plateaus (CTL: 25%; EXP: 20%) determined by arthroscopy. As shown in table 1, no significant differences were found between groups and subgroups in the duration of preoperative symptoms and surgery or of tourniquet time. All patients were operated on as outpatients with the surgical procedure being performed using a tourniquet in all cases, under general anesthesia in 26 (84%) and under spinal anesthesia in 5 patients (16%; 2 EXP, 3 CTL). None had intraoperative or postoperative complications. Finally, patients of both groups were evaluated at similar intervals before and after surgery except for patients in the EXP-F group at the posttest (table 1). They were evaluated about 2 days later than patients in the CTL-F group.

#### Effect of Treatment on Postoperative Work Deficits

Figures 1 and 2 illustrate the mean knee extension and flexion work deficits (30° and 180°/sec) at the pretest and posttest in patients of the CTL and EXP groups, as well as the results of the analysis of covariance. As shown by the bar graphs in figure 1, patients of the EXP group had higher extension work deficits (independent Student *t* tests,  $p < 0.05$ ) preoperatively than patients of the CTL group at both 30° and 180°/sec. These differences in the magnitude

Table 1: Patient Characteristics and General Information About Surgery, Pretest, Posttest, and Follow-up Evaluations

	CTL			EXP		
	F + B n = 16	F n = 11	B n = 5	F + B n = 15	F n = 10	B n = 5
Age (years)	38 (7)*	39 (7)	36 (7)	42 (9)	41 (9)	44 (9)
Weight (kg)	81 (12)	83 (13)	77 (10)	77 (11)	79 (10)	74 (14)
Height (cm)	175 (8)	177 (9)	171 (5)	174 (6)	176 (6)	170 (5)
Duration of symptoms before surgery (weeks)	96 (133)	120 (154)	44 (41)	119 (220)	165 (260)	27 (21)
Duration of surgery (min)	30 (16)	27 (13)	35 (23)	27 (9)	29 (10)	22 (8)
Tourniquet time (min)	31 (16)	28 (13)	37 (21)	32 (11)	35 (12)	26 (7)
Interval between pretest and surgery (days)	4 (4)	5 (5)	3 (3)	6 (8)	5 (3) <sup>†</sup>	10 (14)
Interval between surgery and posttest (days)	23 (2)	23 (2)	24 (2)	24 (2)	25 (2) <sup>†</sup>	23 (2)
Interval between surgery and follow-up 1 (days) <sup>‡</sup>	90 (6)	90 (6)	90 (7)	90 (5)	92 (6)	88 (4)
Interval between surgery and follow-up 2 (days) <sup>‡</sup>	177 (9)	176 (8)	182 (13)	178 (12)	179 (13)	176 (11)

\* Values represent mean (1SD).

<sup>†</sup> Mean (SD) of 14 patients of the CTL group (B, n = 3; F, n = 11) and of 13 patients of the EXP group (B, n = 4; F, n = 9).

<sup>‡</sup> Patients with flap tears were evaluated later (about 2 days) in the EXP group than in the CTL group; independent Student *t* test, *p* = 0.02. No other significant differences (*p* > 0.05) between EXP and CTL groups and subgroups were found.

Abbreviations: B, bucket-handle meniscal tear; F, flap meniscal tear.

of the preoperative deficits between groups were statistically taken into consideration by the analysis of covariance. Indeed, it was suspected that the magnitude of the preoperative deficits might influence the postoperative recovery, especially because a close relationship existed between the preoperative and postoperative deficits in the whole group of patients (*n* = 31; extension 30°/sec: *r* = 0.49, *p* = 0.006; extension 180°/sec: *r* = 0.65, *p* = 0.0001). The results of the analysis of covariance clearly show that patients of the EXP group had a better extension work recovery than patients of the CTL group at 30° (*p* = 0.0001) and 180°/sec (*p* = 0.0008). This is illustrated by the direction of the changes in the mean deficits for both groups. The magnitude of the work deficit after surgery increased in the CTL group whereas it decreased (30°/sec) or was similar (180°/sec) to preoperative levels in the EXP group.

The positive effect of the treatment on the magnitude of the extension work deficits can also be illustrated by studying the relationship between the magnitude of the preoperative and postoperative extension work deficits (fig 4) with simple regression analyses. The slope of the regression lines was steeper for the CTL group than for the EXP group confirming that with a similar level of preoperative work deficit, patients in the CTL group had larger postoperative deficits than patients in the EXP group. In fact, for the same range of preoperative deficits, nearly all patients in the CTL group had higher postoperative deficits than patients in the EXP group (fig 4).

Finally, to estimate the size of the difference in the postoperative deficits associated to the treatment, eight patients of the CTL group were matched with eight patients of the EXP group by the magnitude of their preoperative extension work deficits at 30°/sec (see upper graph of fig 4) and the type of meniscal lesion. As shown in figure 3, with a similar magnitude of preoperative deficit (about 18% at 30°/sec and 12% at 180°/sec; paired Student *t* tests, *p* > 0.05), patients in the CTL group (*n* = 8) had about a 40% deficit at the posttest whereas patients in the EXP group (*n* = 8) had a residual deficit of only 15%, at both speeds of movement.

The direction of changes in the mean flexion work deficits (fig 2) from the pretest to the posttest in each group of patients, was similar to that observed in the extension tests (fig 1). Indeed, the patients of the CTL group had an increase in the magnitude of flexion work deficits from the pretest to the posttest whereas, concomitantly, patients of the EXP group had a decrease, even though both groups had similar flexion deficits preoperatively (independent Student *t* tests, *p* > 0.05). The statistical analysis, however, did not reveal significant differences between groups (ANCOVA, *p* > 0.05) although a tendency (ANCOVA, *p* = 0.08) to lower postoperative deficits in patients of the EXP group was found for the flexion test at 30°/sec (fig 2). The results of the statistical analysis cannot be conclusive because the power of these statistical tests (ANCOVA) to detect an 8% (50% of the mean postoperative residual deficit without treatment) difference between groups, was estimated to be only 22% and 11% for the flexion tests at 30° and 180°/sec. Groups of 64 and 168 patients for the flexion tests at 30°/sec and 180°/sec, respectively, would have been needed to conclude about therapeutic effects with a power of 80%.

### Effect of Treatment According to the Type of Meniscal Lesion

Comparison of the extension work deficits between subgroups (B or F) demonstrated that patients with both types of meniscal lesions gained benefit from the PT treatments. Patients in the EXP subgroups (B and F) had a better extension work recovery (extension tests at 30° and 180°/sec, ANCOVA, *p* < 0.05) than patients in the corresponding CTL subgroups, except for the extension test at 180°/sec in the patients with B lesions (tendency, *p* = 0.06). In the latter case, the probability of revealing differences between groups was, a priori, very low because the power of the statistical test was only (δ = 22%) 30%. Larger groups (*n* = 15) would have been needed for the analysis to be conclusive with a power of 80%.

### Effect of Treatment on Clinical Factors

At posttest, the patients of the EXP group tended to have a lower prevalence of pain during the extension tests both

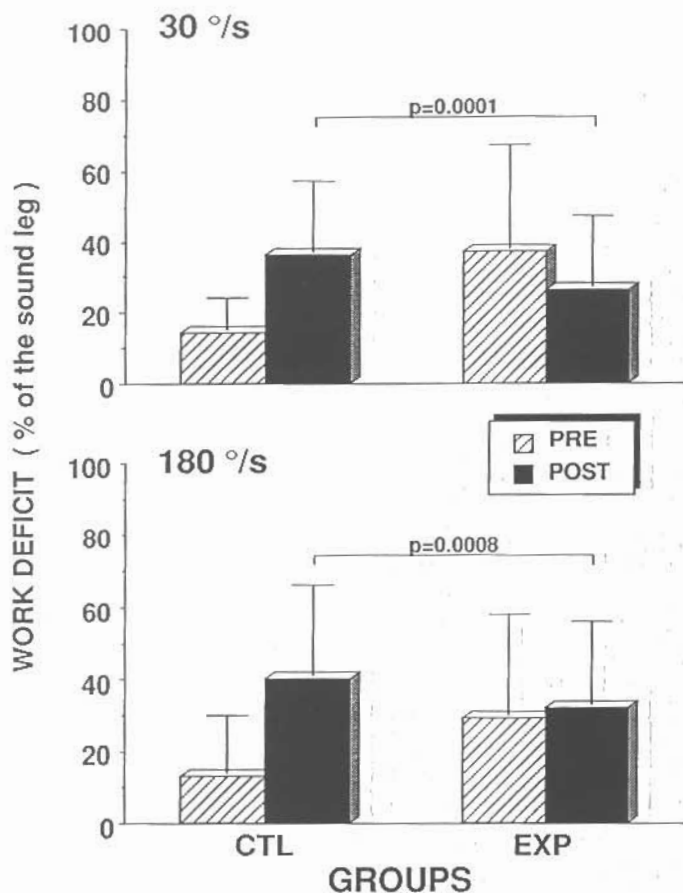


Fig 1—Bar graphs illustrating the mean ( $\pm$ 1SD) extension work deficits (30°/sec: upper graph; 180°/sec: lower graph) at the pretest (stripes) and the posttest (black) in patients of the control (CTL;  $n = 16$ ) and experimental (EXP;  $n = 15$  except for the mean preoperative deficit of the EXP group at 180°/sec,  $n = 14$ ) groups. At the pretest, patients of the EXP group had higher extension work deficits (30°/sec and 180°/sec) than patients of the CTL group (independent Student  $t$  tests,  $p < 0.05$ ; statistical results are not reported in the figure). Results of the analysis of covariance ( $p$  values) are given on the horizontal line.

at 30°/sec ( $p = 0.08$ ) and 180°/sec ( $p = 0.07$ ). In fact, 69% and 56% of the patients of the CTL group felt pain during the extension tests at 30° and 180°/sec, respectively. In contrast, only 33% and 20% of the patients of the EXP group experienced pain during these tests. Moreover, a significantly ( $p = 0.03$ ) larger number of patients of the EXP group had an improvement in the intensity of pain from the pretest to the posttest when performing the extension test at 30°/sec. As much as 60% of the patients of the EXP group felt less intense pain at the posttest than at the pretest whereas only 19% of the patients of the CTL group had such improvement. Conversely, the intensity of pain was worse at the posttest in 38% of the patients of the CTL group, and in only 7% of the patients of the EXP group. The amplitude of knee flexion also tended to be improved ( $p = 0.08$ ) at the posttest in a larger number of patients of the EXP group (EXP, 33%; CTL, 13%) and deteriorated in a larger number

of patients of the CTL group (EXP, 13%; CTL, 50%). No other significant differences between groups were found in the clinical factors studied.

### The Lysholm and Gillquist Questionnaire

No significant differences between groups were found in the functional knee scores obtained at the posttest for the whole sample of patients ( $n = 31$ ; ANCOVA,  $p = 0.56$ ), nor for the subgroups of patients with bucket-handle tears ( $n = 10$ ,  $p = 0.18$ ) or flap tears ( $n = 21$ ,  $p = 0.28$ ). In addition, when the scores obtained at the four evaluation periods were compared, no differences between groups (two-way ANOVA for repeated measures; effect of group,  $p = 0.82$ ) or group by time interaction (MANOVA,  $p = 0.88$ ) were found although a significant effect of time (MANOVA,  $p = 0.0005$ ) was demonstrated. The scores of the CTL and EXP groups were similar at each evaluation (mean  $\pm$  1SD, CTL/EXP: pretest = 74  $\pm$  23/70  $\pm$  19; posttest = 78  $\pm$  19/80  $\pm$  14; follow-up 1 = 88  $\pm$  14/91  $\pm$  10; follow-up 2 = 89  $\pm$  16/91  $\pm$  14) but the scores tended to increase from

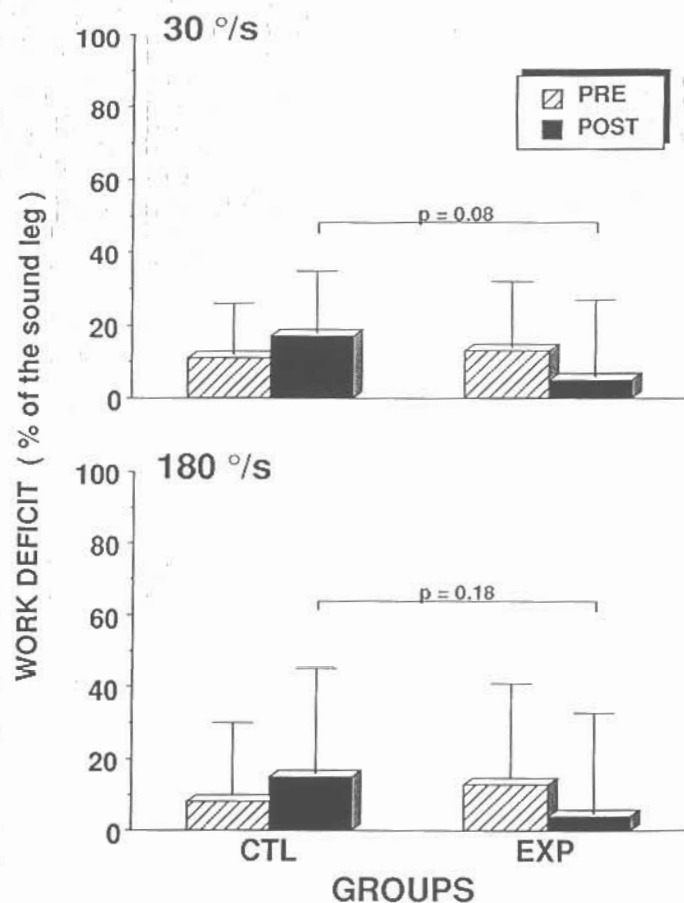


Fig 2—Bar graphs illustrating the mean ( $\pm$ 1SD) flexion work deficits (30°/sec: upper graph; 180°/sec: lower graph) at the pretest (stripes) and the posttest (black) in patients of the control (CTL;  $n = 16$ ) and experimental (EXP;  $n = 15$ ) groups. Results of the analysis of covariance ( $p$  values) are given on the horizontal line.

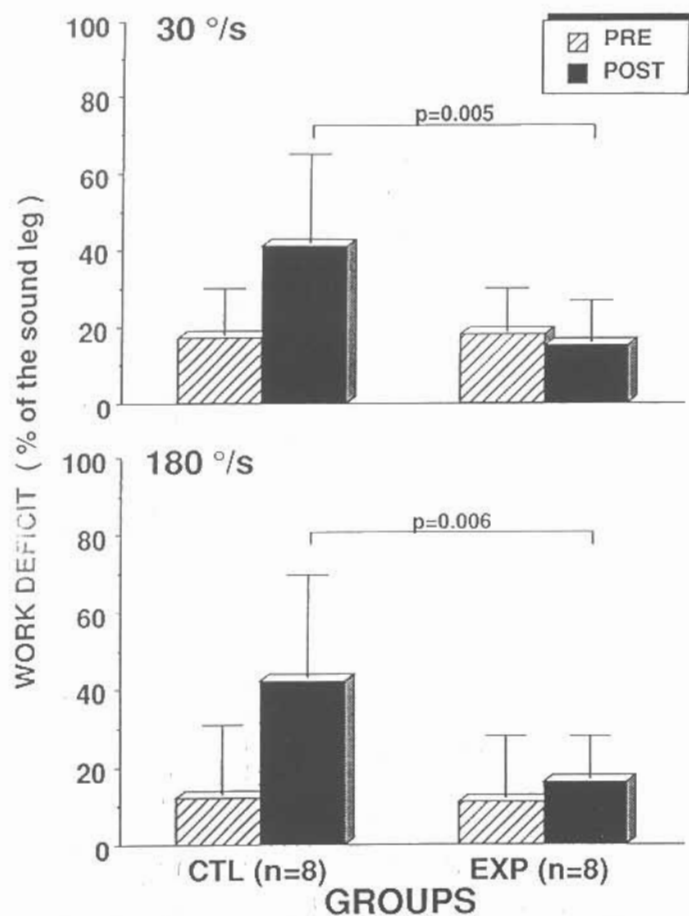


Fig 3—Bar graphs illustrating the mean ( $\pm 1SD$ ) extension work deficits (30°/sec: upper graph; 180°/sec: lower graph) at the pretest (stripes) and the posttest (black) in eight patients of the control (CTL) group and eight patients of the experimental (EXP) group paired by the magnitude of their preoperative extension work deficits and their type of meniscal lesion. Results of the analysis of covariance ( $p$  values) are given on the horizontal line.

the pretest to the last evaluation, 6 months postsurgery. Polynomial contrast analysis revealed a significant linear ( $p = 0.0001$ ) and quadratic ( $p = 0.004$ ) trend over time, but no group effect. Similar results were obtained in the matched EXP-CTL groups ( $n = 8$  patients per group) except that the quadratic trend over time was not significant ( $p = 0.32$ ). Preexisting differences in the level of impairment between groups could therefore not be responsible for the results.

Lastly, the relationship between the extension work deficits and the functional knee scores was examined. Significant correlations ( $p < 0.05$ ) were found between scores and the magnitude of extension work deficits at 30° ( $r = -0.51$ ) and 180° ( $r = -0.40$ )/sec at the posttest and, only at 30°/sec ( $r = -0.40$ ) at the pretest. The strength of these relationships was, however, questionable ( $r < 0.60$ ).<sup>47</sup>

#### Compliance to the Supervised PT Program

Only one patient of the EXP group failed to attend all 9 treatments planned. The majority of the patients followed

the supervised PT program. More than 90% of the patients received TENS and ice, and performed knee mobility and strengthening (ISOM and ISOK) exercises. Moreover, all the patients did bicycle ergometer exercises at the expected sessions and durations. Finally, only few variations were made to the planned treatments among the patients (table 2).

#### Evolution of Clinical Signs and Symptoms in Patients of the EXP Group During the Treatment Period

Figure 5 A illustrates the prevalence and intensity of pain at rest before and after each PT treatment. Only the patients with pain (intensity 1 to 5) are displayed in the figure. The number of patients without pain (intensity 0) corresponds to the difference between the total number of evaluated patients ( $n = 15$  from T1 to T7;  $n = 14$  for T8 and T9) and the number of patients with pain. In general, the prevalence and

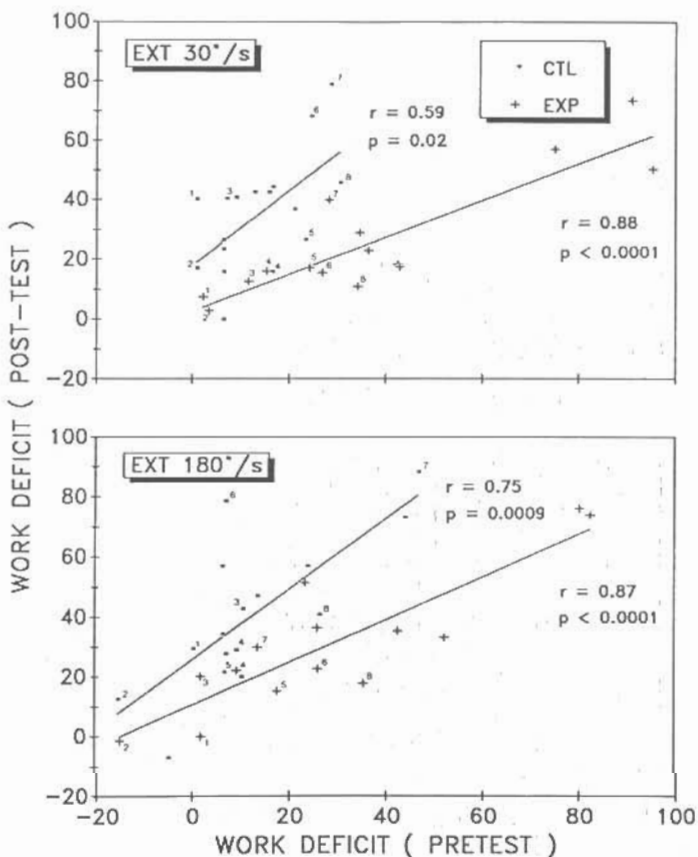


Fig 4—Simple regression lines characterizing the relationships between the magnitude of the preoperative (horizontal axis) and postoperative (vertical axis) extension work deficits at 30°/sec (upper graph) and 180°/sec (lower graph) in patients of the control (CTL; dot) and experimental (EXP; cross) groups. Pearson correlation coefficients and corresponding  $p$  values are reported. The eight pairs (CTL/EXP) of patients matched for the magnitude of their preoperative extension work deficits (30°/sec) and their type of meniscal lesion are designated by similar numbers.

**Table 2: Description of the Nine Supervised Physiotherapy Treatments (T1 to T9) and the Compliance of the 15 Patients (EXP) to These Treatments (at T8 and T9, n = 14 patients) and to the Home Exercise Program**

Modalities	Duration-Intensity	T1	T2	T3	T4	T5	T6	T7	T8	T9
Ice	15min	*	†	*	*	*	*	*	*	*
TENS	20min—HF	*	†	†	7%	7%	7%	7%		
Exercises										
1. Ankle mobility	10 rep	†	†	†	73%	†	73%	73%	71%	71%
2. Knee mobility	10 rep	†	†	†	†	†	†	†	†	†
3. ISOM—Ext 30°	10 rep/10s 30 rep/5s	*	*	*	7%					
4. ISOM—Ext 60°	10 rep/10s 30 rep/5s	†	*	*	33%	7%	7%			
5. ISOM—Flex 30°	10 rep/10s; 30 rep/5s	†	*	*						
6. ISOM—Flex 60°	10 rep/10s; 30 rep/5s	†	*	*	7%	7%				
7. ISOK 60°/s	1 to 3 sets of 10 rep				*	†	†	*	*	*
8. ISOK 120°/s	1 to 3 sets of 10 rep				*	†	†	*	*	*
9. ISOK 200°/s	2 sets of 10 rep							*	*	*
Bicycle ergometer	5 to 30min				*	*	*	*	*	*
Home program	Days without treatments	†	†	†	†	*	†	†	79%	70%

Abbreviations: HF, high frequency; ISOK, isokinetic; ISOM, isometric; min, minutes; rep, repetitions; s, seconds; TENS, transcutaneous electrical nerve stimulation.

Few variations were made to the planned treatments as indicated by the low percentage of patients who received a modality at outside the planned periods. For example, TENS was continued in one patient (7%) from T4 to T7 because of persistence of knee pain.

\* 100% of the patients received the modality with the expected duration and/or intensity.

† >90%.

‡ >80%.

intensity of pain were similar or decreased after each PT treatment, confirming that the treatments did not intensify the pain. The highest prevalence of pain occurred at T3 and T4. Most likely, this was related to the increased level of activity (ADL), cessation of medication or the use of crutches, or the return to work (40%, fig 5B) of the patients in this period. Moreover, from T1 to T9, progressive decreases in the mean ( $\pm$ 1SD) flexion ( $45 \pm 27^\circ$  to  $1 \pm 5^\circ$ ) and extension ( $11 \pm 4^\circ$  to  $2 \pm 3^\circ$ ) movement deficits were observed. The prevalence of inflammatory signs (heat, redness, effusion) also decreased from 93% (14/15 patients) at T1 to 57% (8/14 patients) at the end of the treatment period.

## DISCUSSION

The results of this study demonstrate that an early, intensive, supervised physiotherapy (PT) program, provided in the first 3 weeks after arthroscopic meniscectomy, promotes faster knee extensor strength recovery. The positive effect of the treatment on the strength was impressive because after only 9 supervised treatments combined with a home exercise program, the size of the difference in postoperative extension strength deficits between the groups was as large as 26% (fig 3), and the residual deficits of the untreated (CTL) patients were 2 to 3 times larger than those of the treated (EXP) patients. Patients in the EXP group recovered their preoperative level of extension strength in only 3 weeks as compared to 7 to 12 weeks for patients who did not receive supervised treatments.<sup>3,7,10,20</sup>

The faster rate of strength recovery in patients of the EXP group can be attributed to the effect of the PT program because it is not likely that surgical procedures or other clinical factors biased the postoperative recovery. First, factors such as the type of surgery and the procedures used<sup>7,11,12,15,27,48</sup> could not have affected the results because

all patients underwent an isolated partial medial meniscectomy under similar arthroscopic surgical procedures. Moreover, the duration of surgery<sup>12,27</sup> and tourniquet time<sup>49-52</sup> did not differ between groups (table 1) and none of the patients had intraoperative or postoperative complications.<sup>8,12</sup> Likewise, the age of the patients,<sup>6,9,13,14,53</sup> the prevalence of associated degenerative changes,<sup>1,6,9,12-15,17,27</sup> and the duration of preoperative symptoms<sup>9,12,17,53</sup> were comparable in both groups. Finally, patients of both groups were evaluated preoperatively and postoperatively within similar delays (table 1).

A factor that was different between groups was the size of the preoperative extension strength deficit. It was larger in the EXP group and one can argue that patients with the largest strength deficits are more likely to demonstrate the largest strength improvements.<sup>54-56</sup> The results of the statistical analysis, however, did not support this assumption. First, the analysis of covariance clearly showed that despite this difference in preoperative deficits between groups, great improvement occurred in the EXP group. Secondly, comparison of the subgroups of patients matched for the preoperative strength deficit further confirmed that recovery was greater in the EXP group. Thus, the difference in the size of the preoperative strength deficits cannot explain the superior recovery of the EXP group.

Other unspecified environmental or motivational factors may have partly contributed to the benefits of the PT program (Hawthorne effect<sup>57</sup>). For instance, it is well known that motivation, self-perception of capabilities, therapist-patient interactions, and the belief in the efficacy of the treatment can influence the physical performance or therapeutic outcome.<sup>58</sup> Thus, one can argue that similar positive effects could have been obtained with any other nonspecific type of intervention (or a placebo) providing the patients with the

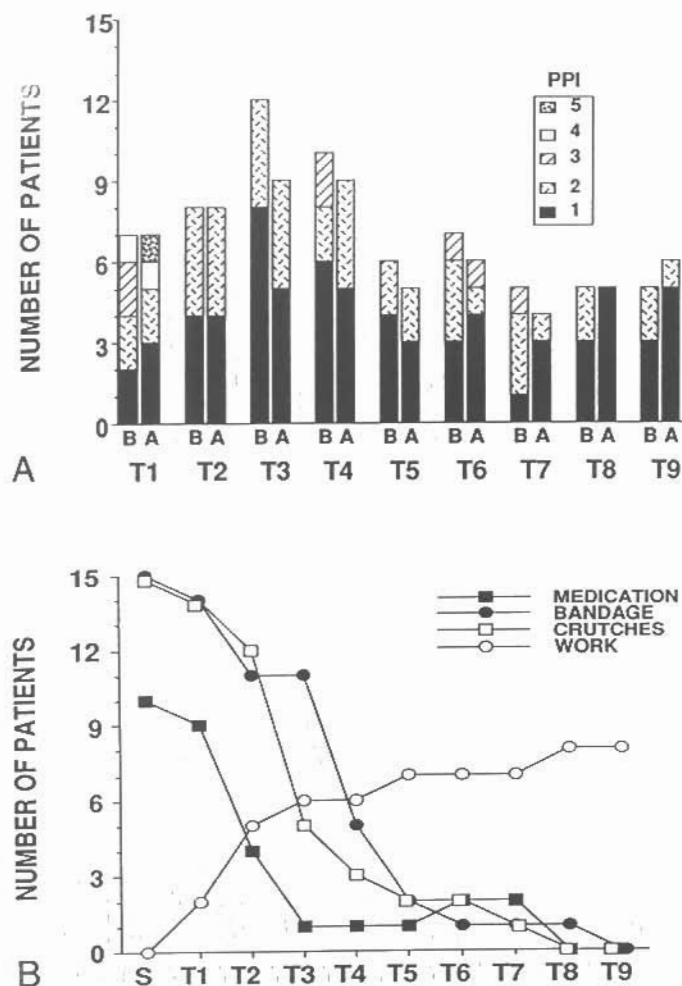


Fig 5—(A) Prevalence and intensity of pain at rest before (B) and after (A) each supervised physiotherapy treatment (T1 to T9) in the group of 15 patients (at T8 and T9,  $n = 14$  patients). The intensity of pain was evaluated with the Present Pain Index (PPI) introduced by Melzack (1975). A score of five reflects an intolerable pain; 4, severe pain; 3, moderate pain; 2, discomforting pain; 1, light pain, and 0, absence of pain. Only the patients with pain (scores 1 to 5) are displayed in the figure whereas those without pain (score 0) are not represented. (B) Number of patients who had taken an analgesic medication used a compressive bandage and/or crutches and returned to work during the rehabilitation period (T1 to T9) in the group of 15 patients. Abbreviation: S, surgery.

same amount of attention and reinforcement. It is, however, difficult to attribute to nonspecific motivational factors the physiological effects observed in the patients of the EXP group. Indeed, the specific positive effects of the modalities used (ice application, TENS, strengthening exercises, bicycle ergometer) in the rehabilitation program have been previously documented<sup>59-62</sup> and some of the modalities, such as TENS, have been shown to be more effective than a placebo in relieving pain<sup>63,64</sup> and accelerating strength recovery.<sup>10</sup> There is also a wide body of literature on the specificity of strength training.<sup>37</sup>

An important finding from our study is that an intense

and early exercise program did not induce ill effects. On the contrary, it appears that our program achieved a good balance between rest and exercises<sup>31</sup> because impressive strength gains were found in patients of the EXP group without concomitant increases in pain, effusion, or loss of joint motion. In fact, the treated patients had a lower prevalence of knee pain during the isokinetic tests than patients of the CTL group. Moreover, always in comparison to the CTL group, improvements in the intensity of pain and in the amplitude of knee flexion from the pretest to the posttest were found in a larger number of patients of the EXP group whereas the prevalence of knee effusion was similar in both groups of patients. Modalities such as TENS,<sup>10,65</sup> ice applications, and use of a compressive bandage in combination with progressive and adapted exercises most likely helped to control and reduce, especially in the first week post-surgery, the undesirable effects of knee pain and effusion<sup>39,40,66-69</sup> thereby favoring efficient strength training even in the early stage postmeniscectomy.

Though a good balance between exercises and rest is essential in an early and intense exercise program,<sup>31</sup> choice of the type of training that will best promote functional gains is also important. For this reason, the exercise program took into consideration the specificity of training that is known to be related to the type of contraction,<sup>37,38,56,70-72</sup> joint position,<sup>38,55</sup> and velocity of contraction.<sup>37,41-43,71,73,74</sup> Although both static and dynamic contractions are necessary, the program was started with isometric contractions at different angles to minimize the stresses on soft tissues and joint.<sup>26,27,30,31</sup> Then, when pain and effusion were less, progressive isokinetic exercises and bicycling were introduced to promote improved dynamic control and endurance.<sup>25,29,30,60</sup> Interestingly, the treated patients were found to have impressive strength gains at both tested velocities of movement (30° and 180°/sec) confirming that ultimately the therapeutic exercises used were efficient to increase strength during both slow and fast velocity movements. The treated patients no doubt had the advantage of training and being tested on similar isokinetic devices.

Strength gains induced by exercises have been attributed to two major adaptations in healthy subjects. The first involves morphological changes in the contractile tissue itself, that is, muscle fiber hypertrophy. The second, referred to as "neural adaptations" or "neuromotor learning," implies changes at different levels of the nervous system that contribute to an improved recruitment (larger number of motor units, higher firing frequency and synchronisation) and coordination of muscles.<sup>25,37,75-80</sup> In the present study, it is likely that the improvements in strength are mainly due to this second type of adaptation because neuromotor learning has been shown to predominate in the first 2 to 4 weeks of training,<sup>76-80</sup> whereas hypertrophy is a delayed process that becomes the dominant factor after 4 to 8 weeks.<sup>37,76,78,80</sup> Moreover, no significant differences between groups were found in the change in thigh circumference from the pretest to the posttest 3 weeks postsurgery.

Even though the rehabilitation program contributed to better knee extensor strength recovery, one third of the patients of the EXP group who had large preoperative knee strength

deficits still presented strength deficits larger than 25% 3 weeks postmeniscectomy. Considering that such large deficits were related to abnormalities in the leg movements and muscle activations when stair climbing,<sup>81</sup> it seems important to reduce these deficits before returning to heavier work-related or sport-related activities. It is also likely that these large strength deficits are due, at least in part, to muscle atrophy. Thus, a longer period of training should favor morphological changes in the contractile tissue itself (hypertrophy), as well as neural adaptations. Therefore, it is likely that a prolongation of the strength training program would lead to a more satisfactory level of recovery in the patients with large deficits (>25%) 3 weeks postsurgery.

Although the knee extensor and flexor muscles were chosen as the target muscles of the early and intensive rehabilitation program, other muscles, especially those contributing to lower limb support and propulsion, may also have been affected by the meniscal lesion, the surgery, and the consequent reduced activities. In our study, bicycling was most likely beneficial for promoting functional lower limb recovery. A more prolonged and complete rehabilitation program should, however, include work for all segments of the lower limb.

As expected, the type of meniscal lesion did not influence the response to the treatment because both the patients with flap (F) and bucket-handle (B) meniscal tears gained benefit from the rehabilitation program. This positive effect of treatment does not mean, however, that strength gains are similar in patients with F and B tears, 3 weeks postsurgery. Patients with B tears, who had larger knee extensor strength deficits preoperatively than those with F tears, tended to remain with weaker knee extensors 3 weeks postsurgery. This tendency was consistent with the finding that the preoperative level of deficit is predictive of the postoperative level. These results disagree with the reports of Hamberg and colleagues<sup>3</sup> who found patients with F tears to have larger extension strength deficits than patients with B tears, 4 weeks postmeniscectomy: the former having a mean deficit of 40% and the latter of 30%. Their conclusion, however, was based on smaller groups of patients (5 patients with B vs 9 with F tears) of different ages with variable prevalences of associated degenerative changes and the size of preoperative strength deficits was not considered in their analysis.

In contrast to the knee extensor muscles, it was not possible to reveal, in the present study, a significant effect of treatment in the rate of strength recovery of the knee flexor muscles (fig 2). A positive trend did, however, occur especially during movements at 30°/sec. Considering that the direction of changes from the pretest to the posttest observed in the knee flexors was similar to that of the knee extensors (figs 1 and 2) and because both groups of muscles were trained, it is likely that the treatment influenced in the same way the rate of strength recovery in both the flexor and extensor muscles. The probability of revealing differences between patients of the EXP and CTL groups in the size of postoperative flexor strength deficits was, however, low. The lack of power is mainly due to the small size of the residual flexion strength deficits of the CTL group ( $\delta = 8\%$ ). A larger

number of patients will be needed to confirm the effect of treatment in the rate of flexor strength recovery.

Finally, the results of the present study suggest that the Lysholm and Gillquist questionnaire<sup>32</sup> is not sufficiently sensitive to evaluate the degree of knee impairment or to follow the strength recovery process. No differences in functional scores between patients of the EXP and CTL groups were found at the pretest even though a large disparity between groups was demonstrated in the size of the preoperative strength deficits. In fact, at the pretest, a difference of more than 20% in mean strength deficits (extension 30°/sec) corresponded to a small difference of less than 5% (4%; CTL =  $74 \pm 23\%$ ; EXP =  $70 \pm 19\%$ ) in the mean functional knee score. At posttest, the difference between groups in the functional scores (2%; CTL:  $78 \pm 19\%$ ; EXP:  $80 \pm 14\%$ ) was also four to five times smaller than for the extension strength deficits (10%; CTL:  $36 \pm 20\%$ ; EXP:  $26 \pm 20\%$ ). Thus, even though a significant relationship ( $r = -0.40$  to  $-0.51$ ;  $p < 0.05$ ) existed in the whole group of subjects between the magnitude of extension strength deficits and the functional knee scores, the functional score seems poorly responsive and only offers an approximative estimate of the maximal knee strength capacity. Thus, one can question the use of such a questionnaire to evaluate postoperative results or to estimate the impact of various surgical interventions or postoperative therapies on knee strength recovery.

In conclusion, the results of the present study convincingly support the institution of an early intensive and supervised rehabilitation program postmeniscectomy by arthroscopy. The rehabilitation program developed was found to be efficient and realistic because it resulted in large strength improvements in a short period of time (nine treatments in 3 weeks) and it was well tolerated by all of the patients. In addition, it offers the advantage of being easily applicable because the modalities of treatment used are well known and available in numerous rehabilitation centers. Thus, the originality of this work was not to propose a new and revolutionary method of treatment but rather to develop, in light of previous works<sup>10,25,27</sup> and the general concepts of rehabilitation,<sup>25,26,30,31,37</sup> an integrated PT program and to demonstrate its efficacy in a randomized controlled trial. The fact that the PT program was provided, for the majority of the patients, during sick leave no doubt influenced the compliance to the treatments. Finally, although the long-term effects of such a rehabilitation program are still not known, the benefits of returning patients to work with better knee function, in the same or perhaps even a shorter delay postsurgery than is usual practice, should justify the economic implication of such an approach.

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