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Isokinetic rehabilitation after arthroscopic meniscectomy

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Summary. The aim of this study was to assess the effects in humans of early (2 weeks) and delayed (6 weeks) isokinetic strength training in the recovery of muscle strength following an arthroscopic partial meniscectomy. The peak torque developed in the quadriceps and hamstrings and the torque developed at a knee angle of 1.05 rad were evaluated in 16 subjects, pre-operatively (pre-op), and 2, 6, and 10 weeks post-operatively (post-op), on an isokinetic device at four different velocities (1.05, 2.09, 3.14, and 4.19 $rad \cdot s^{-1}$). The fatigue characteristics of the muscles were evaluated by having the subject perform 15 maximal contractions at 3.14 $rad \cdot s^{-1}$. Training was done on the same device (three times a week for 1-2 months), beginning either 2 or 6 weeks post-op. A repeated measures analysis of variance demonstrated a time effect but no differences between groups and no interactions. Torques developed by the knee flexors and extensors were significantly smaller 2 weeks post-op than pre-op, at all velocities tested. Torques developed in the quadriceps recovered to their pre-op values by 6 weeks, and further gained significantly in strength from 6 to 10 weeks. Quadriceps torques remained weaker than the contralateral side at 10 weeks. Hamstrings torques were either higher or similar to pre-op values by 6 weeks, and demonstrated increases from 6 to 10 weeks post-op at 1.05 and 4.19 $rad \cdot s^{-1}$ only. Total work and average power developed by the quadriceps and hamstrings during the fatigue protocol changed with time in a similar manner to torque. However, contrary to quadriceps torque, these indices of fatigue were fully recovery by week 10. In conclusion, training in the early stages following arthroscopic meniscectomy does not appear to improve the recovery of strength and the importance of timing of the training stimulus is suggested. Moreover, the results emphasize the need to include a control group when investigating the role of exercise training in the recovery of muscle function.

Key words: Arthroscopic meniscectomy – Exercise training – Recovery

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Introduction

Studies on animals have shown that fast-twitch skeletal muscles are able to recover fully from the nefarious effects of joint immobilization (Fitts and Brimmer 1985; Witzmann et al. 1982) without the benefit of exercise training. It has been shown, however, the exercise training can accelerate the recovery of various muscle properties following a period of disuse (Gardiner et al. 1982; Kasper et al. 1990; St-Pierre et al. 1987). In humans, the acceleration of muscle size and strength recovery through exercise training has been assumed but not conclusively proven. In fact, since a control group of untrained subjects has not been included in the design of previous studies (Elmqvist et al. 1989; Grimby et al. 1980; Halkjaer-Kristensen et al. 1980; Ingemann-Hansen and Halkjaer-Kristensen 1980, 1983, 1985; Knight 1985), it is not known to what extent human skeletal muscles can recover after a period of disuse without supplementing normal activity with exercise training.

In order to determine whether training is beneficial in humans, one must first solve the ethical issues involved in withholding treatment from subjects. With the advent of arthroscopic surgery, it is now possible to partially or totally remove a meniscus with minimum trauma to the knee joint. As not all individuals with this type of surgery are referred to physiotherapy, it is possible to postpone initiation of a strength-training program while avoiding an ethical dilemma. The purpose of this study was to investigate the effects of isokinetic strength training, initiated at 2 and 6 weeks post-operation (post-op), on the recovery of muscle torques in the extensors and flexors of the knee in subjects following an arthroscopic partial meniscectomy.

Methods

Subject population and evaluation procedures. Sixteen subjects who were clinically diagnosed as having a unilateral meniscus problem (mean history ranging from 3 weeks to 7 years) were studied. After obtaining informed consent, a pre-operation (pre-op) evaluation was conducted. It consisted of the following:

1. A clinical assessment of the knee to evaluate pain, range of motion, and ligamentous stability.
2. Bilateral strength measurements of the quadriceps and hamstrings with a computerized isokinetic device (Cybex II+; Lumex, New York, USA). Subjects initially warmed-up on a cycle ergometer at minimal resistance. They were familiarized with the dynamometer and tested at 1.05, 2.09, 3.14, and 4.19 rad·s^{-1}. The speeds were not randomized. Three maximal contractions were recorded at each speed with a 90-s rest between each set.
3. Bilateral fatigue measurements. Subjects performed 15 continuously alternating maximal flexion and extension contractions at 3.14 rad·s^{-1}.
4. Bilateral magnetic resonance imaging (MRI) of the thighs were obtained in 2 subjects 2 weeks post-op and following 1 and 2 months of training. Sixteen 10 mm slices were imaged every 20 mm from the superior border of the patella.

Experimental procedure. All subjects underwent surgery on an outpatient basis with general anesthesia. Four different surgeons participated in the study and a tourniquet was used in every case. Subjects were instructed to put ice on their knee after surgery and were given a home program of exercises to help regain range of motion. They were taught to partially weight bear on crutches for approximately the 1st week post-op. Subjects were re-evaluated 10–14 days after surgery, at which time they were randomly allocated to an early training ($n = 7$) or delayed training group ($n = 9$), using a blocked randomization scheme. Group assignments had been placed in a series of sealed envelopes before the study began. Subjects were re-evaluated 6 and 10 weeks post-op and the evaluator was not informed of the group assignment. During these evaluations, subjects were questionned as to what activity they were doing on their own.

Training protocol. The early training group commenced strength training within a few days of the second evaluation, whereas the delayed training group waited an additional month before training. Training was performed at multiple speeds, on an isokinetic device, three times a week for 4–8 weeks, depending on the willingness of the patient to continue the training. The volume of exercise was progressively increased from two sets of 5 maximal contractions at 1.05, 2.09, 3.14, and 4.19 rad·s^{-1}, to two sets of 11 maximal contractions at seven different velocities (1.05, 1.57, 2.09, 2.62, 3.14, 3.66 and 4.19 rad·s^{-1}), over an 8-week training period. Both groups of subjects started training at week 1 of the program. All subjects warmed-up for 5–10 min on a cycle ergometer at a comfortable load and speed.

Statistical analysis. A Student's *t*-test and Fischer's exact test were used to determine whether baseline characteristics differed between the two groups of subjects. A repeated measures analysis of variance was used to determine possible group (early and delayed training) or time (pre-op, 2, 6, and 10 weeks post-op) effects, as well as possible interactions between time and group. Both absolute (each leg analyzed separately) and normalized (involved limb divided by uninvolved limb) values were analyzed separately at each velocity. If significant ($P < 0.05$) time effects were present, post-hoc analyses were performed to determine which times were different. Paired *t*-tests were also carried out to compare the involved and uninvolved side.

Table 1. Characteristics of the early and delayed training groups

	Early training ($n = 7$)		Delayed training ($n = 9$)	
Age (years)	35.8	(6.0)	35.8	(12.9)
Mass (kg)	75.1	(10.4)	78.7	(13.9)
Height (m)	1.75	(0.08)	1.73	(0.11)
Males (n)	7		6	
Right side involved (n)	1		4	
Right leg dominant (n)	7		9	
Prior activity level:				
moderately active (n)	6		8	
sedentary (n)	1		1	
Medial meniscus tear (n)	4		6	
Posterior horn tear (n)	6		6	
Tourniquet time (min)	27.7	(5.2)	43.1	(23.5)
Tourniquet pressure (mmHg)	380	(105.5)	344.3	(76.8)
Days before full weight bearing	8.0		5.8	
Days before starting home program	4.2		1.6	
Presence of swelling 2 weeks post-op (n)	4		8	
Full range of motion 2 weeks post-op (n)	6		3	

Values are means (SD) or number of patients

Results

The characteristics of the population are described in Table 1. Although the subjects were not classified by the doctor, they were fairly evenly divided into the two groups. One subject in each group had a torn anterior cruciate ligament and one individual in each group had a synovial plica. Two subjects in the delayed training group were found to have a grade two or three chondromalacia lesion on the undersurface of the patella.

Pre-op, the involved quadriceps was significantly weaker than the uninvolved quadriceps at all tested velocities. This was true for both peak torques (12.0–21.0%, depending on the velocity; Fig. 1), and torques developed at a knee angle of 1.05 rad (16.8–20.9% difference; Fig. 2). On the other hand, the involved hamstrings were only weaker than the contralateral side at 1.05 and 4.19 rad·s^{-1}. This was true for both peak torques (15.8 and 21.8%, respectively; Fig. 3) and torques developed at a knee angle of 1.05 rad (13.4 and 20.6%; Fig. 4). Total work and average power developed by the quadriceps and hamstrings during the fatigue test were also lower than normal pre-op findings (Table 2). The fatigue index derived from the ratio of the last three contractions to the first three contractions was similar in both legs (Table 2).

The time course for recovery of the quadriceps was similar in both groups and no significant difference between early and delayed training groups was observed (Figs. 1, 2). Peak torques were significantly lower 2 weeks post-op than pre-op (Fig. 1). The quadriceps had recovered to its pre-op values by 6 weeks post-op and further gained significantly in strength between 6 and 10 weeks post-op (9.9–15.9% increase, depending on the velocity). However, the quadriceps was still significantly weaker than the contralateral side at 10 weeks (7.1–13.2%, depending on the velocity). Similar results were observed for torques developed at a knee joint angle of 1.05 rad (Fig. 2).

The recovery time course of the hamstrings was similar in both groups and no significant difference between

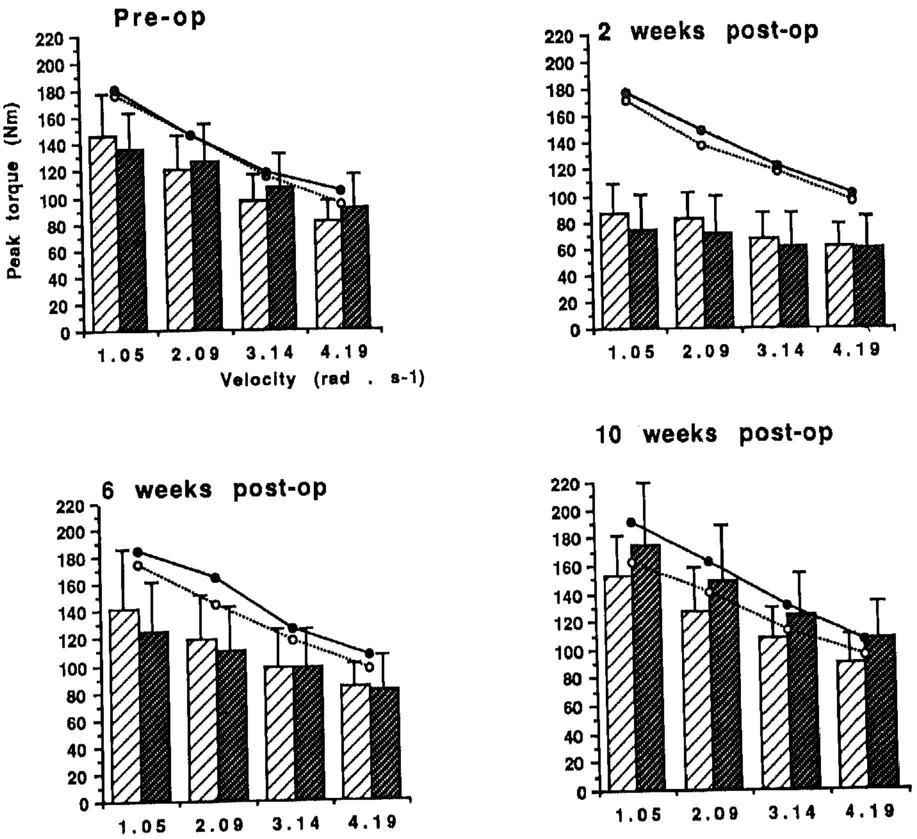

Fig. 1. Quadriceps peak torques of the early training and delayed training groups as a function of velocity of movement. Values are mean (SD). □ Early training; ■ delayed training; ---○--- uninvolved/e; —●— uninvolved/d

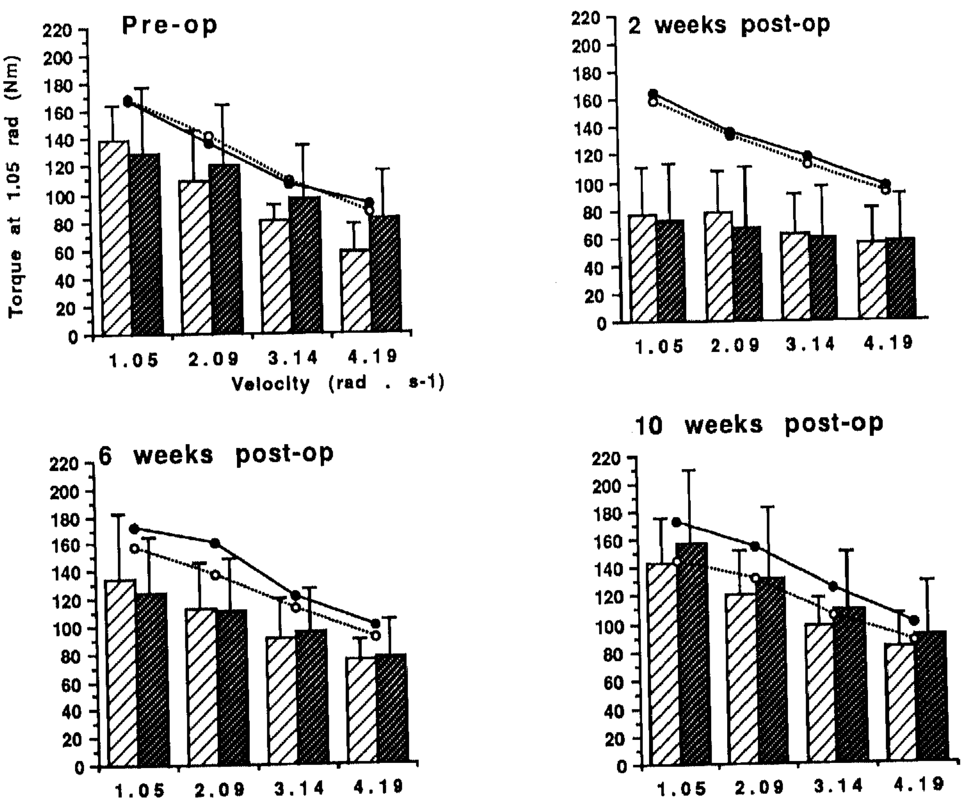

Fig. 2. Torques developed by the quadriceps at 1.05 rad in the early training and delayed training groups as a function of velocity of movement. Values are mean (SD). For symbols see legend of Fig. 1

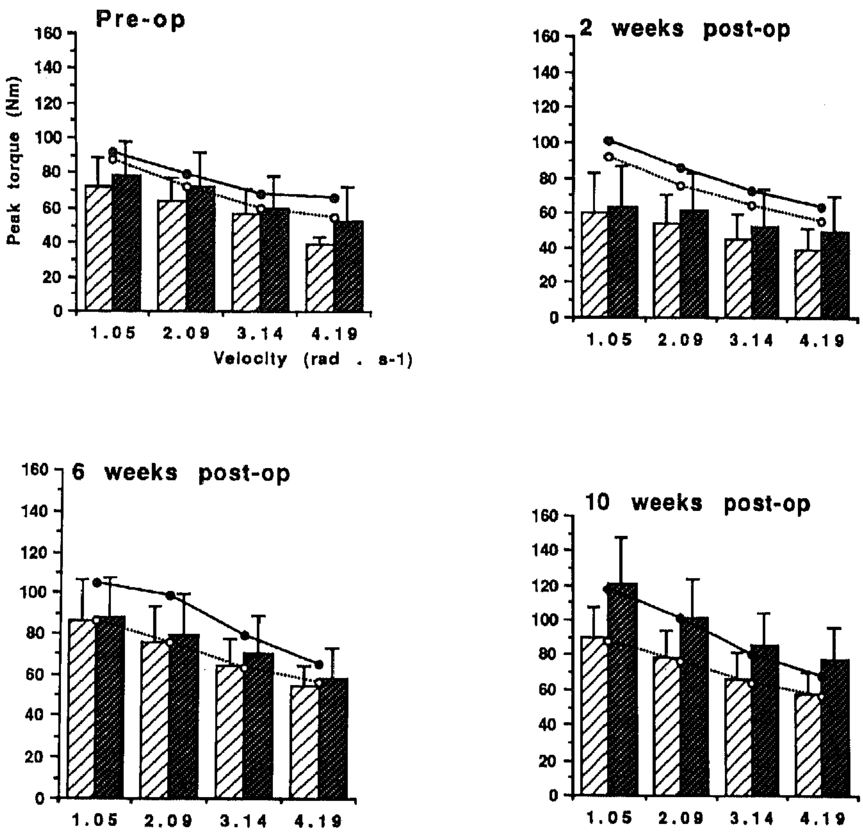

Fig. 3. Hamstrings peak torques of the early training and delayed training groups as a function of velocity of movement. Values are mean (SD). For symbols see legend of Fig. 1

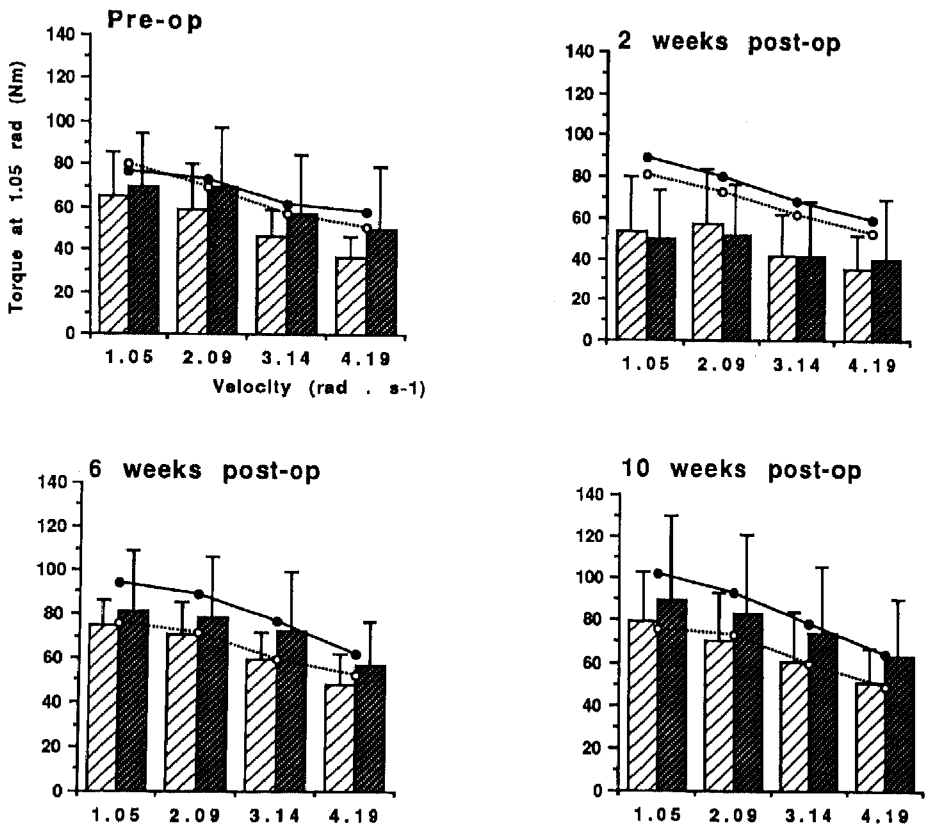

Fig. 4. Torques developed by the hamstrings at 1.05 rad in the early training and delayed training groups as a function of velocity of movement. Values are mean (SD). For symbols see legend of Fig. 1

Table 2. Fatigue characteristics of the quadriceps and hamstrings for the early ($n=7$) and delayed training ($n=9$) groups

		Total work (J)	Average power (W)	Fatigue index
Quadriceps				
Pre-op	Early	1330.6 (326.3)	158.2 (52.7)	78.9 (13.9)
	Delayed	1648.2 (526.0)	187.4 (61.5)	81.5 (18.2)
2 weeks post-op	Early	1006.7 (447.8)	118.5 (29.2)	94.6 (22.6)
	Delayed	896.8 (611.7)	107.2 (64.9)	94.0 (42.7)
6 weeks post-op	Early	1376.7 (371.0)	158.4 (53.4)	79.1 (8.9)
	Delayed	1614.3 (459.3)	185.6 (55.8)	82.6 (14.3)
10 weeks post-op	Early	1565.8 (384.1)	177.7 (52.0)	82.7 (10.1)
	Delayed	1838.9 (637.3)	209.4 (69.9)	77.4 (4.4)
Uninvolved leg mean	Early	1613.9 (379.4)	180.0 (49.8)	74.8 (8.2)
	Delayed	1882.5 (406.5)	214.6 (66.9)	78.4 (14.3)
Hamstrings				
Pre-op	Early	741.1 (237.8)	85.1 (24.2)	74.5 (24.0)
	Delayed	938.5 (493.4)	105.6 (56.1)	79.8 (17.5)
2 weeks post-op	Early	616.4 (354.7)	68.2 (37.7)	67.0 (33.7)
	Delayed	637.0 (572.2)	74.0 (63.4)	92.1 (22.6)
6 weeks post-op	Early	836.8 (270.1)	95.0 (35.1)	63.1 (11.2)
	Delayed	1191.1 (476.5)	134.4 (53.3)	68.4 (18.2)
10 weeks post-op	Early	935.3 (366.9)	104.9 (42.9)	75.3 (10.4)
	Delayed	1311.0 (490.8)	148.0 (54.6)	73.6 (6.3)
Uninvolved leg mean	Early	910.9 (280.4)	99.7 (32.4)	71.3 (14.6)
	Delayed	1253.5 (326.7)	140.9 (50.3)	74.8 (18.5)

Values are means (SD)

early and delayed training groups was observed (Figs. 3, 4). The recovery pattern of the hamstrings was faster then that of the quadriceps. Although strength was lower 2 weeks post-op than pre-op, peak torques of the hamstrings were similar (2.09 $rad \cdot s^{-1}$) or had surpassed (1.05, 3.14, and 4.19 $rad \cdot s^{-1}$) pre-op values by week 6 (Fig. 3). Similar results were observed for torques develop at a joint angle of 1.05 rad (Fig. 4). Paired t-tests indicated that by 6 weeks post-op, the hamstrings were fully recovered. Training from 6 to 10 weeks produced increases in torque at 1.05 and 4.19 $rad \cdot s^{-1}$ only. Torques developed by the uninvolved knee flexors and extensors did not change with time and were similar in both groups (Figs. 1–4).

During fatigue (Table 2), the fatigue index was not a sensitive marker of changes in fatigue characteristics, since no differences between legs, groups or with time were encountered. On the other hand, total work and average power produced by the quadriceps changed similarly to torque, but in contrast, these fatigue indices had recovered fully by week 10 post-op. Total work and average power produced by the hamstrings changed as a function of time in a similar manner to torque, and had fully recovered by week 6 post-op. The fatigue characteristics of the uninvolved quadriceps and hamstrings did not change over the four measured time periods and were similar in both groups.

MRI of the thigh was performed on two subjects and muscle atrophy was evident. The extent of atrophy was found to vary depending on the level of the imaged slice; most atrophy occurred at 3/8 and 4/8 of the distance from the superior border of the patella to the anterior superior iliac spine. The extent of atrophy for both subjects was 13% for the quadriceps and 11% for total muscle. Both subjects trained for 2 months; one was in the early training group and the other in the delayed training group. Training was associated with an increase in muscle size and the amount of atrophy remaining was 3.5 and 6.5% for the quadriceps in subjects 1 and 2, respectively.

Discussion

We have been unable to demonstrate that early isokinetic training is beneficial in the recovery of muscle strength following arthroscopic partial meniscectomy, as both the early and delayed training groups had recovered to their pre-op values by week 6. It is conceivable that this similar improvement in strength could have been due to the fact that subjects in the delayed training group may have exercised sufficiently on their own. Both groups of subjects had been given a home program of exercise to improve range of motion, and these exercises were discontinued once full range of motion had been achieved. The delayed training group had not been given any instructions for strengthening exercises. However, it is difficult to ascertain the degree and intensity of day to day activities that subjects perform on their own and this could constitute a strength training stimulus. All but one of the subjects in the delayed training group had not gone back to regular participation in sports within 6 weeks post-op, and most maintained a very sedentary life-style during the study period. This would suggest that early training is not beneficial in the recovery process following this type of surgery.

The extent of recovery observed within 6 weeks post-op is similar to the findings of Hamberg et al. (1983) who reported that, depending on the type of tear, peak torques of the quadriceps recovered to their pre-op values within 4–8 weeks. The extent of weakness remaining in the quadriceps at 6 weeks post-op at the faster velocities (12% deficit) is similar to that reported by Patel et al. (1982), where a 9% deficit was reported at 3.14 $rad \cdot s^{-1}$. The fact that the hamstrings were fully recovered by week 6 whereas the quadriceps remained weaker than the contralateral side at week 10 corroborates other studies that have demonstrated that the hamstring is either not affected (Thorblad et al. 1985) or recovers faster than the quadriceps in most instances (Krebs 1989; Patel et al. 1982; Vegso et al. 1985).

Both groups of subjects trained from 6 to 10 weeks post-op. Even though the delayed training group was training less intensely than the early training group, similar strength gains were noted, suggesting that the volume of exercise does not have to be high. Although, this increase in strength may not be due entirely to training, results from ongoing research strongly suggest that it is. Indeed, we have been monitoring the recovery of 22 untrained subjects from pre-op to 12 weeks post-op, and have observed that strength gain plateaued from 6 to 12 weeks post-op (Matthews and St. Pierre, manuscript in preparation). The fact that an identical training protocol administered at week 6 post-op produced significant gains in strength whereas it did not ameliorate the recovery process when commenced 2 weeks post-op, suggests that the timing of the intervention may be an important consideration. Similar results have been noted in animal models, where a critical time period for initiating training has been reported for recovery of muscle grafts (White et al. 1984) and after denervation (Herbison et al. 1973). These studies demonstrated that early training did not improve recovery and that training initiated later resulted in a more complete recovery of function than was found in untrained animals. It has also been shown in rats that training may lead to transient injury of muscle recovery from hindlimb suspension, even though recovery was more complete in animals that were trained (Kasper et al. 1990).

Total work and average power developed during the fatigue protocol changed with time in a similar manner for both groups. Fatigability of the quadriceps recovered faster than its maximal torque output, as indicated by the full recovery of the markers of fatigability at 10 weeks, compared with the incomplete recovery of peak torques and torques developed at an angle of 1.05 rad. This would suggest that torque is better maintained during the fatigue protocol, as the muscles were weaker but doing the same amount of work as the contralateral side. The fact that disuse affects the fatigue characteristics of a muscle less than its tension-generating capacity has been similarly reported in animal models of disuse (St-Pierre et al. 1988) and in normal aging (Laforest et al. 1990). Such a finding may be due to the fact that smaller muscles have a smaller diffusion distance for metabolic exchange (St-Pierre et al. 1988).

On the other hand, the fatigue index did not differ for legs, groups or with time, thus demonstrating the insensitivity of this measure of fatigability. This endorses the findings of other studies that have likewise shown the insensitivity and poor reliability of using simple ratios to study changes in the fatigability of muscle (Burdett and Van Swearingen 1987; Ingemann-Hansen and Halkjaer-Kristensen 1985; Montgomery et al. 1989; St-Pierre et al. 1988).

In summary, although the number of subjects in the study was small, our results do not indicate that training in these subjects was beneficial in the first few weeks post-op. The timing of training may be an important consideration in the recovery process after arthroscopic meniscectomy. Moreover, the results emphasize the need to include a control group when investigating the role of exercise training in the recovery of muscle function. In the absence of a control group, it has to be questioned whether a training effect is solely responsible for the strength improvement reported in other studies (Grimby et al. 1980; Halkjaer-Kristensen et al. 1980; Ingemann-Hansen and Halkjaer-Kristensen 1980, 1983, 1985; Knight 1985).

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