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IMPACT OF KNEE EXTENSOR STRENGTH DEFICITS ON STAIR ASCENT PERFORMANCE IN PATIENTS AFTER MEDIAL MENISCECTOMY

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ABSTRACT. After arthroscopic meniscectomy the relationship between the magnitude of knee extensor strength deficits and locomotor performance during stair ascent unloaded and when carrying a 22 kg load has been tested in 31 patients. The specific locomotor adaptations related to large strength deficits were also studied. The results indicate that large deficits were significantly associated to: 1) reduced activation of the knee extensor muscles (vastus medialis and lateralis) during the first double leg support and single leg support phases, and of the hip extensors (medial hamstrings) during the second double leg support of stair ascent, 2) overactivations of the hip extensors (gluteus maximus and medial hamstrings) during single leg support, and 3) longer cycle and step durations and lower cadences. Locomotor abnormalities in movements and muscle activations were generally found in patients with strength deficits greater than 25% while patients with smaller strength deficits (less than 25%) usually could climb stairs with normal performance. These results support the use of knee extensor strength measures to predict locomotor capacities, and also highlight the importance of postoperative knee strength rehabilitation.

Key words: muscle strength, isokinetics, functional test, stair ascent, muscle activation, meniscectomy.

Muscle weakness and locomotor disabilities are known to occur after meniscectomy (ME). Although arthroscopic procedures favour an accelerated post-operative recovery (6, 15, 18), knee extensor strength deficits as large as 30% to 40% persist 3 weeks postmeniscectomy (6, 8, 20) and a residual deficit of about 20% is still present 7 to 8 weeks postsurgery (6, 8). On the other hand, locomotor recovery seems to be faster since patients usually walk unassisted within one week postsurgery (3, 15, 18, 20). Quantitative assessment of gait, stair ascent and descent have, however, contradicted this assumption by revealing significant changes in muscle activations and movements 4 weeks and velocity up to 8 weeks postmeniscectomy (4).

The progressive recovery of strength and locomotor activities supports the general belief that the ability to perform locomotor activities is closely related to knee extensor strength. The functional impact of the size of strength deficits postmeniscectomy on locomotor activities, however, has not been described. It is of interest to clarify this relationship because of the potential value of using strength deficits to predict locomotor capacities. Indeed, it is very difficult to detect clinically subtle changes in movements during locomotor activities and, it is practically impossible to discern motor strategies involved in movement compensations (26). Furthermore, evaluations of gait kinetic and kinematic patterns are usually not possible in most clinical settings. There is thus a need to develop predictive tests based on relationships between simply obtained measures such as strength and locomotor performance.

The main purpose of this study is to evaluate the relationship between the magnitude of knee extensor strength deficits and locomotor performance in a group of 31 patients, 3 weeks after a partial medial meniscectomy by arthroscopy. Stair ascent unloaded and with a 22 kg load were used as functional locomotor tests that would be demanding enough to unmask abnormal leg movements and muscle activations associated with small strength deficits. Estimates of the functional demand placed on knee extensor muscles by comparison of activation levels during various locomotor activities have shown stair ascent unloaded and with a 22 kg load to require about 65% (12, 22) and 82% (12) of maximal capacity, respectively.

The research hypotheses were the following: 1) the magnitude of the knee extensor strength deficit is directly related to the extent of abnormalities in movements, muscle activations (EMG) and temporal characteristics during stair ascent tests with and without load, and 2) in patients with small strength deficits, some abnormalities would be revealed only in the stair ascent test with load.

SUBJECTS AND METHODS

Subjects

Thirty-one men aged between 22 and 56 years (mean age: 40 years, SD $\pm$ 8; range: 22 to 56 years) who were scheduled for medial ME by arthroscopy, attended 2 testing sessions. At the first session (mean 5 days before surgery, SD $\pm$ 6), the knee extensor strength of both legs was measured. At the second session, 3 weeks postmeniscectomy (mean 24 days, SD $\pm$ 2), only the operated leg was retested, and the locomotor performance during stair ascent unloaded and with 22 kg was evaluated. The postoperative strength deficit of the operated leg was established by comparison with the sound leg. Movement and EMG deficits and changes in temporal characteristics during stair ascent tests were determined by comparing the locomotor performance of the ME subjects to that of 15 healthy men (normal group; mean age 28 years, SD $\pm$ 5) without musculoskeletal disorders of the lower extremities.

The group of ME subjects were initially recruited for a randomized controlled trial designed to evaluate the effects of a specific physiotherapy treatment program. They signed an informed consent before being evaluated preoperatively and were randomly allocated the day of the surgery to either a treatment or non treatment group. In the interval between the surgery and the second testing session, the 15 ME subjects who were allocated to a treatment group, received 9 physiotherapy treatments, whereas, the other 16 ME subjects had, as was the usual practice, a nonsupervised home exercise program. The superiority of the supervised physiotherapy program to promote knee extensor strength recovery has been reported (14). In parallel to the study of the treatment efficacy, this project offered the opportunity to study the relationship between strength deficits and locomotor performance since at the second testing session (3 weeks postmeniscectomy) both strength and locomotor performance during stair ascent were evaluated. To study such a relationship, the treated and untreated ME subjects were combined ($n = 31$) because the different postoperative management most likely increases the range of strength deficits in the total group and thereby privileges the study of the relationship between the deficits and other variables such as those defining stair ascent.

Methods

Evaluation of stair ascent. All subjects performed two stair ascent tests consisting of 1) 9 trials of stair ascent unloaded and 2) 9 trials of stair ascent with an external load of 22 kg. The sequence of the stair tests was systematically alternated among subjects to control for the possible effects of fatigue or familiarization with the tests. The two stair tests were carried out at free speed, interspersed by a 5 min rest period and followed, for the ME subjects, by a 10 min rest period and the isokinetic strength test. During the stair tests, the sagittal movements of the hip, knee and ankle joints were recorded by a TRIAX electrogoniometer (Chattecx Corporation, Chattanooga, TN), which has been shown to give reproducible and valid angle measures during gait (7). The muscle activation (EMG) of 6 leg extensor muscles: gluteus maximus (GM), medial hamstrings (MH), vastus medialis (VM), vastus lateralis (VL), medial gastrocnemius (MG) and soleus (SO), was picked up with surface electrodes (Meditrace silver-silver chloride, 11 mm). In the first 4 normal and 9 ME subjects, EMG from the GM and SO muscles were not recorded. To reduce movement artefacts, the electrodes were connected to miniature preamplifiers, then to a channelling box attached to the subject's back and via a 10 m shielded cable, to the electrode selector unit of a GRASS polygraph (model 7D, Grass Instrument Company, Quincy, MA). The EMG signals were amplified and recorded as raw EMG on the polygraph paper to allow for visual inspection of the signals before being rectified and time-averaged with a time constant of 0.02 sec. In 3 ME subjects, artefacts were observed in either the VM, VL, or MH making it necessary to remove these EMG records from our data base. The movement and EMG data were recorded from the right leg of normals and the operated leg of ME subjects. Temporal parameters of stair ascent were determined from pressure sensitive footswitches taped to the heel, mid-foot and toe of both shoes. Footswitch, electrogoniometric and EMG signals were recorded simultaneously with a sampling frequency of 100 Hz and processed by computer (IBM AT).

For the stair tests, the subjects ascended a flight of 3 steps (slope of the stairs: 34 degrees) without holding the bannisters. Each trial of stair ascent began by a step on the floor with the nonevaluated leg from a standardized starting position (landmark placed at a distance equal to 40% of the subject's height from the staircase). The stair ascent cycle began with the initial contact of the foot of the evaluated leg on the first step and ended when the same foot contacted the third step. Thus, only one cycle could be recorded for each trial of stair ascent. For the test with 22 kg, a special jacket with 4 pouches (2 in the front and 2 in the back) was designed to hold bags of lead shot. Added weight was thus carried on the front and back of the trunk just above the center of gravity at the sacral level and the load was balanced. This load carrying system does not induce significant changes in the hip and ankle movements of normal men ($n = 15$) and induces only minor changes (< 5 degrees) in the knee movement profile (12).

Evaluation of isokinetic strength. The maximal voluntary isokinetic strength of the knee extensor muscles of both legs (the sound leg was always evaluated first) of the ME subjects was measured at 30 degrees per second on a computer-controlled Kin-Com dynamometer (Chattecx, Chattanooga, Tennessee). The subjects sat with the hip flexed approximately at 120 degrees and stabilized by straps across the trunk, pelvis and thigh. The center of rotation of the Kin-Com rotational axis was aligned to the approximate center of rotation of the knee joint and the dynamometer arm was attached on the leg above the ankle. The isokinetic test consisted of 3 maximal voluntary contractions (MVCs) through an arc of 90 degrees interspersed by a 1 min rest period. Before the isokinetic tests, the subjects warmed up by making 10 graded submaximal knee extension-flexion movements at 60 degrees per second. All subjects received the same instructions and were encouraged verbally to give their maximal effort during tests. A maximal static contraction of 2 sec preceded each dynamic contraction to minimize the effect

Table I. *Summary of significant correlations between magnitude of isokinetic extension work deficits, and changes in muscle activations (EMG deficits) and temporal variables during stair ascent unloaded (left column) and when carrying 22 kg (r values in bold in the right-hand column), in 31 subjects after medial meniscectomy*

Stair ascent variables	Pearson correlation coefficients
EMG deficits in DLS(1)	
VM	0.42*/**0.42***
VL	0.50**/**0.48****
EMG deficits in SLS	
VM	0.43*/**0.27**
VL	0.40*/**0.26**
MH	−0.55**/**−0.54****
GM[1]	−0.50*/**−0.53***
EMG deficits in DLS(2)	
MH	0.10/**0.40***
Temporal variables	
Cycle duration	0.37*/**0.46****
Step duration	0.41*/**0.44***
Cadence	−0.36*/**−0.49****

*$p<0.05$, **$p<0.01$; significant correlations.
[1]GM ($n=22$); VM, VL and MH ($n=30$).

of force development on the dynamic strength record (3, 5). Force, angle and velocity signals from the Kin-Com dynamometer were simultaneously recorded at a sampling frequency of 400 Hz.

Data analysis. For each stair test, the 5 cycles with the durations closest to the mean cycle duration of the 9 trials recorded, were retained for analysis to limit the effects of different velocities on EMG (28). For graphical representations, EMG and movement profiles ($n=5$) were first normalized to a stair cycle of 100% and mean values (±2 standard errors) per group were calculated at each 2% of the cycle (Fig. 1). For the analyses, the stance period was also normalized to 100% and thereafter, was subdivided into 3 functional segments (DLS1: first double leg support, 0–25% of the stance phase; SLS: single leg support, 25–75% of the stance phase; DLS2: second double leg support, 75–100% of the stance phase). Areas under the movement and EMG profiles ($n=5$) for these 3 segments were calculated. These area values were chosen as the representative movement and EMG variables for statistical analysis. Furthermore, the difference in the EMG levels and movements between the two stair tests was quantified by establishing a "percent change with load" for each subject with the following formula:

$$\%\ \text{change with load} = \frac{(\text{area value for the 22 kg test} - \text{area value for the 0 kg test})}{\text{area value for the 0 kg test}} \times 100$$

Forces measured during the isokinetic tests were corrected for passive forces due to limb weight and the lever arm (3, 21). For each MVC, the variable "work", defined as the area under the moment-angle curve in the constant velocity phase of movement (10 to 70 degrees of knee flexion), was calculated. Then, the largest work value of the 3 contractions was used to establish a work deficit (in percent of the sound leg) for the operated leg 3 weeks postmeniscectomy.

Statistical analysis

The relationship between the stair variables and the magnitude of the work deficits was studied with Pearson's correlation coefficients. To examine further the relationship between the magnitude of the work deficit and performance during stair ascent, the total group of ME subjects was subdivided into 2 groups: 1) ME < 25% group: 15 ME subjects with work deficits less than 25%, and 2) ME > 25% group: 16 ME subjects with work deficits larger than 25%. The locomotor performance and the anthropometric characteristics of the 2 groups of ME subjects and the group of normals ($n=15$) were compared with an analysis of variance (GLM procedure; SAS statistical software; SAS Institute Inc., Cary, NC). Since some variables were not distributed normally, differences between groups were also tested with Kruskal-Wallis analyses and similar results were found. In the present report, only the result of the analysis of variance is reported. Scheffe's test was used for post-hoc multiple comparisons. The level of significance was set at $\alpha=0.05$.

RESULTS

Relationship between work deficits and stair performance in ME subjects

Positive correlations ($p<0.05$) were obtained between the magnitude of work and EMG deficits for the VM and VL during DLS1 and SLS, and for the MH during DLS2 (Table I). This indicates that greater work deficits are related to higher EMG deficits (lack of activations) in the VM, VL and MH during these specific support subphases. Moreover, in both stair tests, EMG deficits in the VM and VL (DLS1 and SLS) were also positively correlated (r values ranged from 0.41 to 0.76), as was the VL during DLS1 and the MH during DLS2 of the loaded test ($r=0.50$). This suggests that the two knee extensor muscles (DLS1 and SLS) and the MH during DLS2 were affected in the same way by the knee impairment.

Negative correlations were found between work and EMG deficits in the two hip extensor muscles (GM and MH) during SLS of both stair tests (Table I). This indicates that the hip extensors increased their level of activation (overactivation) with larger knee extension work deficits. This overactivation of hip extensors was associated with decreased activation of knee extensors in DLS1 (r values from −0.38 to −0.44).

No significant relationships were found between the magnitude of work deficits and movement changes for

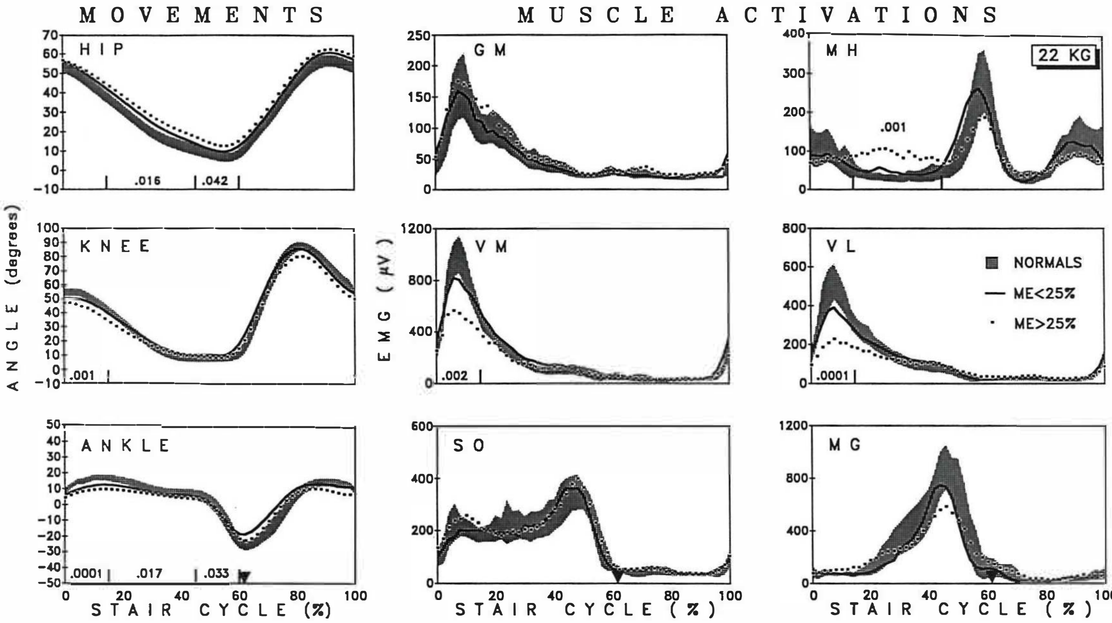

Fig. 1. Mean movement profiles of the hip, knee and ankle joints and muscle activation profiles of 6 leg extensor muscles (gluteus maximus, *GM*; medial hamstrings, *MH*; vastus medialis, *VM*; vastus lateralis, *VL*; medial gastrocnemius, *MG*; soleus, *SO*) of 2 groups of subjects after meniscectomy (ME) (solid line: 15 ME subjects with extension work deficits less than 25%; *dotted line*: 16 ME subjects with work deficits larger than 25%) are superimposed on the mean (± 2 SE) of a group of 15 normal subjects (shaded area) for the loaded (22 kg) stair ascent test. Significant differences between groups (ANOVA, $p < 0.05$) in each support subphase (DLS1: first double leg support, 0% to 15% of the cycle; SLS: single leg support, 15% to 45% of the cycle; DLS2: second double leg support, 45% to 60% of the cycle) indicated by vertical lines and corresponding p values. Triangles indicate the end of the stance phase (60% for ME groups and 61% for normal group).

the 3 segments of the stance phase of stair ascent. Cadence and cycle and step durations of the ME subjects during both stair tests were, however, significantly related to the magnitude of the work deficits (Table I). As expected, stronger relationships were found during the loaded stair test. In both tests, the ME subjects with the largest work deficits had, in general, the longest cycle and step durations, and the lowest cadences.

Comparison of stair ascent performance of ME and normal subjects

In general, the movement and EMG profiles of the ME subjects with small deficits (ME < 25%; mean deficit: $14 \pm 7\%$; $n = 15$) were similar to those of the normal group in the 3 support subphases during both stair tests (for the loaded test see Fig. 1). The only exception was the reduced ($p < 0.05$) ankle dorsiflexion in DLS1 during the loaded test in the group of ME subjects (< 25%) compared to the group of normal subjects (Figs. 1–2). The mean dorsiflexion deficit was estimated to be 31%, as illustrated by the bar graph in Fig. 2. In the group of ME subjects with large work deficits (> 25%), ankle dorsiflexion in DLS1 was even more reduced during both the loaded and unloaded tests.

Many other modifications (in comparison to the ME group with small work deficits and normal subjects) were found in the movement and EMG (VM, VL and MH) profiles of the group of ME subjects with large deficits (ME > 25%; mean deficit: $47 \pm 15\%$; $n = 16$). Indeed, the ME subjects had less knee flexion, less ankle dorsiflexion and smaller activation bursts in the VM and VL during DLS1 of the stair test unloaded. Similar modifications occurred in DLS1 of the loaded test (Fig. 1), except that the knee and ankle movements of the two ME groups were not significantly different (Fig. 2). These results are also illustrated as mean percent change values in Figs. 2 and 3. In SLS for the two stair tests, the ME subjects with

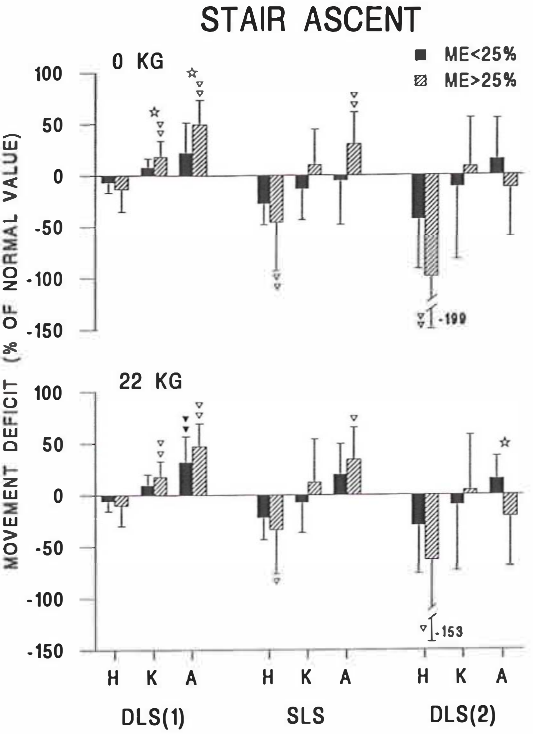

Fig. 2. Bar graphs illustrating the mean (±1 SD) movement deficits at the hip (*H*), knee (*K*) and ankle (*A*) joints (established in percent of the mean normal values) during the 3 support subphases (*DLS1*: first double leg support; *SLS*: single leg support; *DLS2*: second double leg support) of stair ascent unloaded (0 kg; upper graph) and when carrying 22 kg (lower graph). Where statistical differences between groups were found (ANOVA, $p<0.05$; see Fig. 1), post-hoc multiple comparisons (Scheffe's tests) between groups were performed. *Triangles* indicate significant differences between ME groups (*full triangles*: ME<25% group; *open triangles*: ME>25% group) and normal group (▿ $p<0.05$; ▿▿ $p<0.01$) while stars (☆) indicate significant differences between the 2 ME groups.

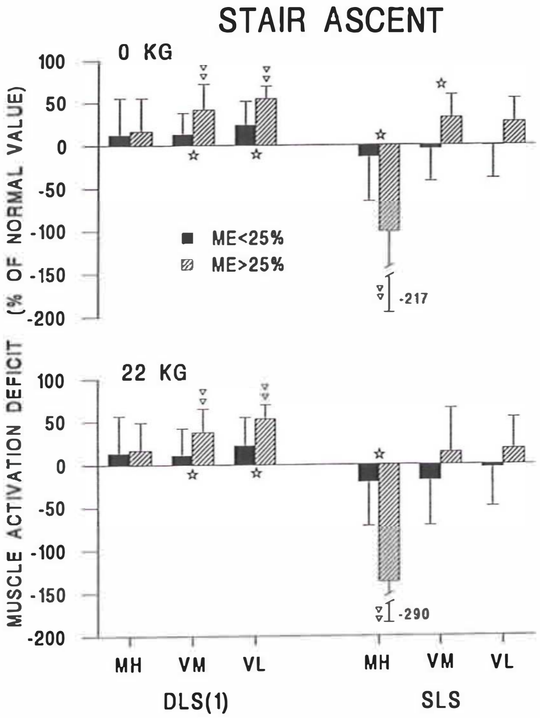

Fig. 3. Bar graphs illustrating mean (±1 SD) muscle activation deficits (established in percent of the mean normal values) in 3 extensor muscles (medial hamstrings, *MH*; vastus medialis, *VM*; vastus lateralis, *VL*) where significant changes were found between groups (see Fig. 1). Upper graph reports the results for stair ascent unloaded and lower graph, the stair ascent test when carrying 22 kg. *Triangles* and *stars* indicate significant differences between groups (see caption of Fig. 2 for details).

large work deficits adopted a more flexed position at the hip, had less dorsiflexion at the ankle and had an overactivation in the MH muscles (Fig. 1). This pattern is represented by mean percent deficits of −46% and −33% at the hip, 30% and 34% at the ankle and, −101% and −137% in the MH for the unloaded and loaded tests respectively (Figs 2 and 3). Finally, in DLS2, only two significant differences were found between groups: the subjects of ME>25% group maintained a more flexed position at the hip than normal subjects during both tests and, they also had a lower range of ankle plantarflexion compared to subjects of the ME<25% group (Fig. 2).

Comparison of temporal variables during the stair tests in ME and normal subjects

During the loaded test, the ME subjects with large work deficits had a longer cycle duration than the ME subjects with small deficits (Table II). No other significant differences in the temporal variables of the stair cycle were found between groups.

Comparison of age and anthropometric data of the ME and normal subjects

The ME subjects with small and large work deficits, and the normal subjects had similar anthropometric characteristics (weight, height). The group of normal subjects (mean age 28.2, SD ± 4.6) were, however, younger ($p<0.05$) in comparison with the two groups of ME subjects (ME<25%, mean age 40.2, SD ± 7.0; ME>25%, mean age 39.5, SD ± 9.2).

Table II. *Comparison of temporal variables of stair ascent unloaded and when carrying 22 kg in the 3 groups of subjects*

	Stair ascent unloaded				Stair ascent with 22 kg			
	Groups				Groups			
	ME < 25%[1] (n = 15)	ME > 25%[2] (n = 16)	Normals (n = 15)	ANOVA Prob	ME < 25% (n = 15)	ME > 25% (n = 16)	Normals (n = 15)	ANOVA Prob
Cycle duration (s)	1.3 ± 0.1[3]	1.5 ± 0.3	1.5 ± 0.1	0.14	1.4 ± 0.1	1.6 ± 0.4	1.5 ± 0.2	0.04*
Step duration (s)	0.6 ± 0.07	0.7 ± 0.02	0.7 ± 0.09	0.05	0.6 ± 0.1	0.7 ± 0.2	0.7 ± 0.1	0.04*
Cadence (steps/min)	90.1 ± 7.7	83.4 ± 16.3	83.3 ± 8.0	0.21	89.4 ± 7.6	78.9 ± 17.6	82.3 ± 8.3	0.06
% stance	59.6 ± 2.4	60.0 ± 3.5	60.8 ± 2.3	0.51	60.6 ± 3.2	62.3 ± 4.4	62.1 ± 2.5	0.36
% DLS (1)	13.6 ± 2.4	14.7 ± 4.0	14.6 ± 3.1	0.59	15.7 ± 3.7	16.0 ± 3.2	16.4 ± 3.8	0.87
% SLS	31.0 ± 6.5	32.0 ± 3.4	32.6 ± 4.3	0.68	28.8 ± 8.3	29.5 ± 5.0	31.1 ± 3.5	0.62
% DLS (2)	15.0 ± 7.1	13.3 ± 2.3	13.3 ± 4.7	0.60	16.1 ± 7.9	16.9 ± 5.6	14.6 ± 2.3	0.57

[1] Subjects who had a meniscectomy with isokinetic extension work deficits smaller than 25%.
[2] Subjects who had a meniscectomy with isokinetic extension work deficits larger than 25%.
[3] Mean ± 1 SD.
* Significant differences between groups (one-way analysis of variance, $p < 0.05$). Scheffe multiple comparison tests revealed a significant longer cycle duration in ME subjects with large extension work deficits (> 25%) comparatively to ME subjects with small deficits (< 25%) in stair ascent with 22 kg.

Comparison of percent change with load in the ME and normal subjects

In normal subjects, load-carrying during stair ascent induced few changes in the movement profiles while large EMG increments were observed in all six extensor muscles during the stair stance phase. These EMG increments reported in percent of the EMG levels recorded during the stair test unloaded, or % change with load, varied from 17% in the SO to 30% in the GM during DLS1, and from 10% in the MH to 40% in the MG during SLS (Fig. 4). Moreover, in these two first support subphases, the % changes with load in the VM and VL were about 20% while in the GM, they were 30% (Fig. 4).

Although inter-group differences were observed in the mean EMG% changes induced by load-carrying, these differences were, usually, not significant with the exception of the three following variables: the VM and VL during SLS and the hip during DLS2. This lack of differences between groups for the majority of the variables is, most likely, due to the large intersubject variation illustrated by the large standard deviations in Fig. 4. This variability among the subjects suggests that different muscle load compensation synergies are used to climb stairs with an additional load (13).

The % changes with load in the knee extensors during SLS were, however, larger for the ME subjects (42% and 34%) with large work deficits comparatively to normal subjects (19% for VM and VL). This suggests that the knee extensor muscles when submitted to a higher functional demand such as during SLS with load, can considerably increase their activation levels. Note, however, that the activation levels of the VM and VL did not reach normal levels (Fig. 1). Normal subjects adopted a more flexed position at the hip when load-carrying (% change with load: 59%). In contrast, the ME subjects with large deficits had only minor changes in the hip movement from one stair test to the other (% change with load: −2%). This lack of change in the hip movement of the ME subjects may be explained by the fact that during the unloaded test, they already had a more flexed position at the hip than the normal subjects and therefore they did not further increase their hip flexion.

DISCUSSION

In this study, the magnitude of isokinetic strength deficits of the knee extensors was found to be related to leg movement and muscle activation deficits during stair ascent in ME patients 3 weeks after a partial medial meniscectomy. Large deficits were usually associated with: 1) reduced activation of the knee extensor muscles during the first double leg support

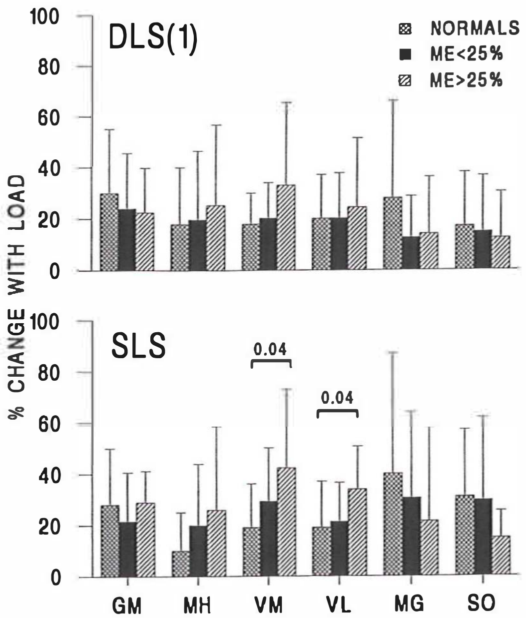

Fig. 4. Comparison of the mean (±1 SD) percent changes with load in muscle activation levels of the 6 leg extensor muscles (gluteus maximus, *GM*; medial hamstrings, *MH*; vastus medialis, *VM*; vastus lateralis, *VL*; medial gastrocnemius, *MG*; soleus, *SO*) during the first double leg support (*DLS*1, upper graph) and single leg support (*SLS*, lower graph) of the stair cycle. The horizontal brackets and the corresponding *p* values indicate significant differences between groups (ANOVA, $p<0.05$) in the % change with load.

(DLS1) and single leg support (SLS), and in the hip extensors (MH) during the second double leg support (DLS2) of stair ascent, 2) overactivations in the hip extensors (MH and GM) during the SLS, and 3) longer cycle and step durations and lower cadences. These findings support the clinical assumption that the strength of the extensor muscles acting across the knee is a major determinant of stair ascent performance. Moreover, it implies that the magnitude of the knee strength deficit can be used to estimate the capacity of patients to ascend stairs with normal motor patterns.

Among the ME patients studied, there appeared to be a threshold knee strength deficit that subdivided the patients into a group with or without abnormal motor patterns. Patients with a deficit less than 25% tended to climb stairs with "normal" movement and EMG profiles. This was supported by the finding that when the strength threshold to subdivide the patients was increased to 30%, some locomotor abnormalities were discerned in the group of patients with small deficits. For example, in patients with a deficit less than 30%, adaptations were observed only at the ankle (as in the ME<25% group during the stair ascent with a 22 kg load) and in the VL. In patients with deficits larger than 30%, adaptations were also observed in the movements and muscle activations of the knee and hip, suggesting a sequence to the pattern of adaptations.

The magnitude of the strength deficit was, most likely, not the only factor to influence the stair ascent performance of the ME subjects since the correlation coefficients were relatively low, not exceeding 0.55 (Table I). Thus, never more than 30% (r^2 in percent) of the EMG deficits and temporal changes during stair ascent could be explained by the size of the strength deficit. Moreover, other factors such as: the presence of pain during weight bearing, effusion, movement limitations, joint deformations, instability and articular degenerative changes have been related to gait abnormalities in patients with rheumatoid arthritis and/or osteoarthritis of the knee joints (10, 19, 23).

Studies describing the functional demand of different locomotor tasks have demonstrated that stair ascent requires about 65% of the maximal knee extension capacity (12, 22). This suggests that patients with strength deficits up to 35% should be able to meet the force requirement of stair ascent. Even stair climbing with a 22 kg load attached to the trunk, a task known to require 82% of maximal knee extensor capacity (12) should not be demanding enough to reveal strength deficits less than 20%. It is thus not surprising that ME<25% group of patients (mean deficit = 14%) could execute both the unloaded and loaded stair ascent tasks without abnormalities. As expected, ME subjects with deficits larger than 25% (mean deficit = 47%) had abnormalities in the movements and muscle activations during stair ascent. When further stressed by ascending stairs with load, similar abnormalities were found. They apparently react like normal subjects by increasing the level of activation (% change with load) in their 6 leg extensor muscles (Fig. 4) while only mildly modifying movements at the hip, knee and ankle. The percent increase in the activation levels of the knee extensors during SLS, however, is about twice that seen in the normal subjects (Fig. 4). This excessive knee activation adaptation with load may be related to either muscle weakness or to the removal of inhibition to meet the demands of the task.

The comparison of movement and EMG profiles of the subjects of the ME > 25% group with those of the normal group was useful to pinpoint the specific functional adaptations related to large knee strength deficits. These adaptations can be directly associated to the meniscal lesion and subsequent meniscectomy since all ME subjects were free of other known musculoskeletal or neurological disorders. The reduced muscle activation levels of the knee extensors during DLS1 and SLS, and the MH during DLS2, are not likely related to a reduced cadence (27, 28) because similar cadences were found between the groups of ME subjects with large and small deficits (Table II). The movement and muscle activation adaptations found at the adjacent segments (hip and ankle) are thus consequent to the impairment of the joint and muscle control at the knee. These adaptations most likely contribute to decrease knee joint stresses, joint pain and muscle demands placed on the knee extensor muscles (2, 16, 23).

The most evident adaptations were reduced knee flexion, especially at the beginning of the stair cycle, and low knee extensor muscle activations. These reduced activations may help decrease the compressive joint force by avoiding strong muscle contractions around an unstable flexed knee as described in patients with knee arthritis (23). Moreover, by decreasing knee flexion at the beginning of the cycle, the force requirement to extend the knee is also reduced (16, 17). Similarly, the slower speed of progression most likely leads, as in gait, to lower vertical ground reaction forces transmitted across the knee joint (27) and less muscle power and energy generated at the knee (25). Furthermore, the more flexed position at the hip throughout the cycle, related to trunk forward lean, increases the demand placed on the hip extensors but decreases the demand on the knee extensors by displacing the trunk center of mass anterior to the knee joint axis (2, 16, 17). The overactivation in the MH and the tendency to higher levels of activation in the GM may reflect the larger torques generated by the hip extensors to stabilize the hip. Moreover, the reduced extensor capacity at the knee must be compensated for by increased activity of other leg extensors to meet the needs for support of the body in an upright position and insure forward progression (11, 16, 17, 24). Interestingly, only the hip extensors were brought into play to compensate for inadequate knee extensors since no significant changes occurred in the ankle plantarflexors. Similar compensations, i.e. forward lean of the trunk and overactivation of the MH, have been previously described in patients with total knee arthroplasty (1, 9).

Motor strategies used by normal subjects during stair ascent (between successive strides and between subjects) have been shown to be more stereotyped at the knee and ankle, whereas the hip is more variable, especially in the SLS phase (11). Interestingly, in this study, major compensations in the ME > 25% group involved the hip. Moreover, one of the most characteristic muscle compensations, the overactivation in the MH, occurred during SLS. The hip adaptations may be the most energy efficient while preserving the need for a stable ankle position over the support foot.

The fact that stair ascent with a 22 kg load did not reveal larger or additional locomotor adaptations than stair ascent alone in the 2 groups of ME patients, with the exception of the ankle movement (Fig. 2), may suggest that carrying a 22 kg load did not sufficiently increase the muscle demand placed on the extensor muscles. To reveal differential adaptations, it may be necessary to compare the performance of a larger number of patients, grouped into smaller ranges of deficits. For example, a group of patients with deficits ranging between 20% to 35% would be expected to have adaptations only in the loaded test.

In conclusion, although it is not possible to explain completely the stair ascent abnormalities by the magnitude of the knee extensor strength deficit, the existence of a significant relationship between these variables highlights the importance of postoperative knee strength rehabilitation to favour functional locomotor recovery.

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