

Federico Balagué
Margareta Nordin
Ali Sheikhzadeh
Anne-Catherine Echegoyen
Mary Louise Skovron
Hans Bech
Dominique Chassot
Maurits Helsen

Recovery of impaired muscle function in severe sciatica

Received: 2 June 2000
Revised: 20 September 2000
Accepted: 9 October 2000
Published online: 9 January 2001
© Springer-Verlag 2001

F. Balagué (✉) · H. Bech · D. Chassot
M. Helsen
Hôpital Cantonal, Fribourg, Switzerland
e-mail: balaguef@hopcantfr.ch,
Tel.: +41-26-4267383,
Fax: +41-26-4267387

M. Nordin · A. Sheikhzadeh
Hospital for Joint Diseases,
New York University Medical Center,
New York, USA

A.-C. Echegoyen
Fribourg, Switzerland

M. L. Skovron
Genentech Inc., South San Francisco,
California, USA

F. Balagué
Service de Rhumatologie,
Médecine Physique et Rééducation,
Hôpital Cantonal,
1708 Fribourg, Switzerland

Abstract This is a prospective cohort study of patients with acute treated severe sciatica. The objectives of the study are, firstly, to describe the recovery of muscle performance by manual and isokinetic muscle testing in patients with acute severe sciatica over 1 year, and secondly, to discuss the potential clinical relevance of the isokinetic testing of the ankle for patients with acute sciatica. In clinical daily practice, muscle performance is evaluated by means of isometric manual tests. Different authors using manual muscle tests have reported the long-term outcome of the muscle function in patients with sciatica. Overall, the results are good in terms of the recovery of muscle strength. However, it is not clear whether the isometric strength is sufficiently relevant to evaluate the more complete muscle performance of the affected muscles in patients with sciatica. This study presents data on the muscle recovery measured with manual testing and isokinetic testing of patients with severe sciatica. Consecutive patients admitted to the Cantonal Hospital for conservative management of severe acute sciatica were eligible for inclusion in the study. Patients were evaluated at admission, discharge, and follow-up at 3, 6, and 12 months. All the visits included a standardized clinical examination and the completion of questionnaires. Imaging and electromyography were conducted at the first visit. Isokinetic muscle tests at 30°/s and 120°/s were performed at discharge and follow-up visits. Man-

ual and isokinetic tests were performed on foot and ankle flexor and extensor muscles. Eighty-two consecutive patients (66% men), with a mean age of 43 (± 10.3) years, entered the study. The prevalence of major muscle weakness was low, with 7% of patients unable to perform toe walking and 11% unable to walk on the heel at visit one. Moreover, motor deficit defined as a score of 4 or less (out of 5) was found in 15% of subjects at the first evaluation. Such severe deficits were not found during the last three visits. The isokinetic tests showed a higher prevalence of muscle function impairment. At visit 5, the isokinetic test showed impaired muscle function recovery from 23% to 32%, while the manual test showed almost full recovery. The issues of agreement between manual and isokinetic muscle testing are discussed. In this selected and homogeneous cohort of patients, the prevalence of motor deficit was rather low and the outcome excellent according to the results of the manual testing. Isokinetic muscle tests showed a higher prevalence of deficit and a much slower recovery. The manual muscle test is a crude clinical test. For more in-depth muscle performance evaluation, additional testing may be necessary, especially for those patients with physically demanding jobs or activities.

Keywords Sciatica · Outcome assessment · Isokinetic muscle test · Clinical tests · Manual muscle testing

Introduction

The recovery of patients with sciatica is usually good [1, 4, 6, 10, 13, 27, 30]. The recovery of muscle performance is not well understood, but it is usually rated good to excellent if positive improvement is shown by manual muscle testing. Manual muscle testing, part of a clinical standard evaluation [2, 11] that is aimed at determining muscle integrity, can only detect major muscle performance differences between the involved and uninvolved lower extremity. Furthermore, muscle endurance is functionally important, but is poorly tested with an isometric manual muscle strength test lasting a few seconds. A more refined measurement would involve the use of isokinetic strength and endurance testing of the dorsal and plantar flexor muscles of the ankle.

Studies of the recovery of long-term muscle performance are lacking in the literature for patients with sciatica. The potential role of isokinetic testing in terms of clinical practice has never been evaluated for patients with severe sciatica. Better understanding of the recovery of muscle strength and endurance could lead to improved recommendations for muscle performance testing and treatment to regain full capacity for physically demanding activity and/or work.

We have observed that the usual manual muscle tests are not sensitive enough to evaluate ankle and foot flexor/extensor muscle performance in sciatica patients once the phase of acute pain has subsided. Our hypothesis was that a more demanding test, such as an isokinetic test, would show a higher prevalence of muscle function impairment in acute sciatica patients. This is particularly important for patients with high functional demands at work, leisure or at home.

Purpose of this study

The purpose of this study was:

1. To describe the recovery of ankle muscle performance by manual and isokinetic muscle testing in patients with acute severe sciatica over 1 year, and
2. To discuss the potential clinical relevance of isokinetic testing for patients with acute severe sciatica

Materials and methods

This is a prospective cohort study of patients treated for severe acute sciatica pain. Patients were enrolled during the acute phase (mean duration of pain 32 days, range 1–154 days). Materials and methods have been described elsewhere in detail by Balagué et al. [5].

Population

Consecutive patients hospitalized in the Cantonal Hospital, Fribourg, Switzerland for treatment of severe sciatica were evaluated for inclusion in the study. Swiss physicians in this Canton refer a large percentage of patients suffering from sciatica of radicular ori-

gin to the Cantonal Hospital. The main reasons for hospitalization are: intensive pain management (including bed rest, epidural injections, medication and other measures), neurological deficit, and living too far from the hospital for ambulatory treatment, according to local standards. Even if a majority of non-surgical hospitalizations for LBP have been considered inappropriate in the literature, some indications can be considered “medically” necessary [8]. The treatment at the hospital in-patient program includes bed rest (1 week), medication (narcotic analgesics, NSAIDs, sedatives), physical medicine modalities, TENS, exercise in a swimming pool, instruction, and gymnastics. Epidural steroid injections were performed when pain intensity remained high enough to interfere with the rehabilitation program. The average duration of hospitalization is 3 weeks. Cauda equina syndrome and progressive motor deficit (manual motor test score <3) were indications for immediate surgery. Surgery was elective for intolerable pain refractory to aggressive drug therapy, or for lack of improvement after 2–3 weeks of hospitalization. Similar indications have already been published by others [17, 31].

Inclusion criteria

All the patients admitted to the Department of Rheumatology, Physical Medicine and Rehabilitation of the Cantonal Hospital for conservative management of sciatica were considered potentially eligible for inclusion in the study. Sciatica was defined according to the diagnostic categories 4 and 6 from the Quebec Task Force [29] and had to be unilateral with or without low back pain (LBP). Spitzer classified pain in several ways: category 4 is defined as pain and radiation to the lower limb and neurological signs; and category 6 is defined as compression of spinal nerve confirmed by specific imaging techniques, e.g., computed tomography (CT), myelography or magnetic resonance imaging (MRI), or other diagnostic techniques, e.g., electromyography (EMG) or venography. Patients with acute first episode of sciatic pain and patients with previous episodes of sciatica but without symptoms for at least 1 year immediately prior to the current episode were eligible. Only patients with involvement of a single nerve root (L5 or S1) were included, and they were evaluated by means of a standardized protocol over the period of 1 year [5, 7, 24].

The level of the involved nerve root was determined by the topography of pain from a pain drawing, and the neurological examination including sensitivity, reflex and muscle testing, and electromyography.

Exclusion criteria

The exclusion criteria were the inability to understand, read, and respond to questionnaires in the French language; age over 65 years; previous spine surgery; recent (≤ 1 year) vertebral fracture; major spinal deformities; spondylolisthesis; diabetes mellitus and/or other metabolic/endocrine disorders with polyneuritis; known alcoholism or drug abuse; lower limb fracture within the past year; lower limb amputation; recent ankle sprain; and other possible causes of sciatica such as obstetric/gynecological disorders.

Informed consent

The ethical committee of the hospital approved the project. Informed consent was obtained from all participating patients. The study was initiated on November 1993 and the follow-up of the last patient was conducted on November 1998.

Process

Subjects were evaluated five times: at admission and discharge from the hospital, and then at 3, 6, and 12 months after discharge

(visits 1–5). The first evaluation (visit 1) was performed within the first 24 h of admission, and the second evaluation took place during the last 2–3 days in the hospital. Clinical evaluation at admission (visit 1) and at discharge (visit 2) was performed by the treating physician. Follow-up evaluations (visits 3–5) were performed by an independent physician. The evaluations were standardized [5, 7, 24] according to an agreement between the physicians reached during the pilot study. An inter-observer study between these physicians was performed with ten sciatica patients not included in the study for the straight leg raising test and spinal mobility ($R=0.88–0.98$, $P<0.05$).

Data collection

Data collected at admission included demographics, standardized clinical examination (including orthopedic and neurological examination), self-administered questionnaires [5, 7, 24] (functional status by Oswestry [14], pain visual analog scale, quality of life [32]), electrodiagnostic (EMG) examination, and imaging (CT scan or MRI), and blood specimens. These results are reported elsewhere [5]. At discharge and during the follow-up visits (visits 2–5), the standardized clinical examination was performed, questionnaire data were collected, and an isokinetic ankle muscle performance test was performed by independent physical therapists.

Manual muscle testing

Manual muscle testing was performed in the supine position according to Kendall and Kendall [20]. The great toe extensor and the dorsi-flexors of the foot as well as the plantar flexors of the foot were tested [20]. The ankle and foot extensor muscles were labelled the L5 group, while the plantar flexor muscles were considered the S1 group. For each test, the score of the weakest muscle was recorded for the L5 and S1 muscle groups according to a scale from 0 to 5, where 0 is no activity in the muscle and 5 is full/normal activity of the tested muscle or muscle group. In our area, clinical practice conventionally allows scoring of the muscle strength between the manual muscle test score of 4 and 5 with sub-scores of 4+ and 5-. These sub-scores were collapsed into 4 and 5 for analysis, as we did not have any method to validate the clinical manual testing sub-scores.

Isokinetic muscle testing

All study patients were subjected to an isokinetic evaluation of the ankle flexor and extensor muscles at visits 2 through 5 (four times). During the pilot phase, it appeared that at visit 1 the patients had too much pain to perform the isokinetic test. Therefore, the first isokinetic measurement was performed at discharge, when the patient had received treatment and the acute pain of sciatica had abated. The dynamic plantar and dorsal muscle tests were performed with an isokinetic dynamometer (Biodex 2000, Biodex Corp., Brookhaven R&D Plaza, Shirley, NY, USA). The subjects were lying on their side, and the first test always started with the

uninvolved leg to benefit from the learning effect on the sciatica leg. After warm-up and a few learning trials, the patients were asked to perform three complete ankle plantar flexion and dorsal extension cycles at 30°/s and then 15 complete cycles at 120°/s. Then, the involved leg with sciatica was tested. The isokinetic patient database comprised the values of torque and total work generated from the Biodex patient report. The isokinetic data were analyzed as absolute data and as the ratio of the involved to the uninvolved leg. Ratios for plantar flexor and dorsal extensor muscle groups were computed for each visit. In isokinetic muscle testing in normal individuals, a strength difference between the two sides of up to 15% is considered to be within normal limits [23].

Reproducibility of isokinetic muscle testing

Prior to this study, we performed a reproducibility study for ankle testing with the Biodex B-200 isokinetic dynamometer in order to analyze the performance of the equipment during calibration. Additionally, we sought to study intra-subject reliability in three different postures of the ankle joint. The calibration test for 30°/s and 120°/s showed a standard error ranging from 0.3 to 0.04 for peak torque and total work in flexion. In the subject reliability study, we then tested ten healthy volunteers [six men and four women, age 32 (± 7.4) years] three times in three positions: side lying, prone lying, and sitting. Each test consisted of three maximal flexion-extension cycles at 30°/s and fifteen complete maximal cycles at 120°/s. Both ankles were tested in each position. A total of 90 subject tests were performed. The side lying position was found to be the most acceptable position for the subjects, and the position with the best reproducibility. Intra-class correlation showed good (≥ 0.90) to acceptable (≥ 0.70 to < 0.90) correlation for peak torque, total work, and average power (0.94, 0.92 and 0.73, respectively) in flexion. In extension, the correlation coefficients were similar for peak torque, total work, and average power (0.83, 0.84, 0.89, respectively). The remaining measures were poorly correlated, and thus not used in this study. Based on the results of the reproducibility study, we chose to use the parameters of peak torque, average power, and total work and to test the patients in the side lying position. The reproducibility study also demonstrated random strength differences of up to 18% between the left and the right side. We therefore conservatively set the recovery index involved/uninvolved ratio to ≥ 0.85 .

Statistical analyses

For baseline and follow-up data, descriptive statistics were computed, as appropriate for categorical and continuous variables.

This study was initiated prior to the recognition of the need to block the range of motion in isokinetic testing according to the performance of the injured leg. Therefore, we explored ranges of motion by testing for significant differences with a paired *t*-test between the involved and uninvolved leg for each visit (visits 2–5). There was no significant difference ($P>0.05$).

The following isokinetic data were considered as missing data in our data analysis:

Table 1 Number of individuals with limp (score yes/no), unable to toe walk (score yes/no), unable to heel walk (score yes/no), and manual muscle testing (score < 4) for the involved leg in patients with sciatica (L5 and S1) over five visits. Numbers in parentheses indicate percentage of population

Clinical variables	Visit 1 (admission) ($n=82$)	Visit 2 (discharge) ($n=80$)	Visit 3 ($n=72$)	Visit 4 ($n=72$)	Visit 5 ($n=74$)
Limp (present)	31 (38%)	6 (8%)	4 (6%)	2 (3%)	4 (5%)
Heel walk (unable)	9 (11%)	5 (6%)	0	0	0
Toe walk (unable)	6 (7%)	1 (1%)	0	0	0
Motor deficit < 4 ; L5 and S1 (yes)	12 (15%)	4 (5%)	0	0	1 (1%)

Table 2 Isokinetic means (SD) for peak torque (PKT), total work (TW) and average power (AP) for the involved (IN) and uninvolved (UN) leg in patients with sciatica: values for dorsal and plantar flexion^a. Isokinetic testing was performed at discharge, and at 3, 6, and 12 months (visits 2–5) at 30°/s and at 120°/s. Mean (SD) ratios (*Ratio*) are expressed as a percentage (involved/uninvolved×100)

	Visit 2		Visit 3		Visit 4		Visit 5	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Dorsal flexion 30°/s								
PKT UN (Nm)	80	29 (8)	70	29 (7)	70	28 (8)	72	30 (9)
PKT IN (Nm)	80	23 (9)	70	27 (8)	71	27 (9)	71	26 (8)
<i>Ratio (%)</i>	80	81 (25)	69	92 (21)	69	96 (24)	71	90 (22)
TW UN (Nm)	75	58 (20)	70	55 (16)	67	51 (16)	70	55 (16)
TW IN (Nm)	78	42 (19)	68	51 (19)	70	51 (20)	69	50 (18)
<i>Ratio (%)</i>	73	75 (28)	67	96 (31)	65	101 (33)	67	91 (23)
AP UN (Nm)	80	10 (3)	70	10 (2)	70	9 (3)	72	10 (3)
AP IN (Nm)	80	8 (3)	70	9 (3)	71	9 (3)	71	9 (3)
<i>Ratio (%)</i>	80	81 (28)	69	95 (27)	69	99 (30)	71	92 (25)
Dorsal flexion 120°/s								
PKT UN (Nm)	81	16 (5)	71	15 (4)	73	15 (5)	72	16 (6)
PKT IN (Nm)	81	13 (5)	71	14 (5)	74	15 (5)	71	14 (4)
<i>Ratio (%)</i>	81	81 (26)	71	96 (25)	73	101 (33)	71	95 (24)
TW UN (Nm)	78	136 (50)	67	123 (42)	69	117 (72)	66	117 (50)
TW IN (Nm)	73	111 (56)	68	119 (59)	71	112 (55)	70	111 (50)
<i>Ratio (%)</i>	70	81 (34)	64	99 (35)	65	112 (60)	65	100 (38)
AP UN (Nm)	81	15 (5)	71	14 (4)	73	13 (6)	72	13 (5)
AP IN (Nm)	81	12 (6)	71	13 (5)	74	13 (6)	71	12 (5)
<i>Ratio (%)</i>	81	83 (34)	71	98 (33)	73	106 (52)	71	97 (33)
Plantar flexion 30°/s								
PKT UN (Nm)	80	53 (21)	70	60 (22)	69	64 (25)	71	65 (26)
PKT IN (Nm)	80	40 (20)	69	52 (20)	71	58 (23)	71	58 (25)
<i>Ratio (%)</i>	80	77 (34)	68	90 (28)	68	93 (24)	70	90 (26)
TW UN (Nm)	75	99 (43)	70	108 (44)	67	110 (44)	70	116 (51)
TW IN (Nm)	78	67 (39)	68	90 (41)	70	102 (41)	69	97 (43)
<i>Ratio (%)</i>	72	71 (34)	67	87 (31)	65	92 (30)	67	88 (31)
AP UN (Nm)	80	17 (7)	70	20 (8)	69	22 (9)	71	22 (9)
AP IN (Nm)	80	13 (7)	70	17 (7)	71	20 (9)	71	19 (9)
<i>Ratio (%)</i>	79	78 (38)	68	91 (39)	68	90 (25)	70	91 (32)
Plantar flexion 120°/s								
PKT UN (Nm)	81	36 (14)	71	36 (12)	73	36 (14)	70	36 (13)
PKT IN (Nm)	81	23 (12)	71	31 (13)	74	32 (14)	71	31 (13)
<i>Ratio (%)</i>	81	67 (31)	71	87 (29)	73	90 (27)	69	91 (29)
TW UN (Nm)	78	309 (143)	67	300 (128)	69	284 (134)	67	291 (127)
TW IN (Nm)	73	186 (112)	68	251 (121)	71	257 (132)	70	250 (136)
<i>Ratio (%)</i>	70	66 (37)	64	88 (38)	66	95 (41)	66	91 (41)
AP UN (Nm)	81	34 (17)	71	34 (14)	73	33 (15)	70	34 (14)
AP IN (Nm)	81	21 (13)	71	28 (14)	74	29 (16)	71	30 (16)
<i>Ratio (%)</i>	81	64 (39)	71	87 (36)	73	92 (37)	69	93 (40)

^a The different values for *N* reflect the fact that only cases with all the scheduled repetitions recorded were included in the analysis. Moreover, some patients missed totally or partially one or more

evaluations. Overall, only nine patients decided to interrupt the study, and were considered drop outs

1. Data of patients who did not perform the isokinetic test or did not show up at the follow-up
2. Data of patients for whom the Biodex patient report did not generate a value for selected measured variables

We also explored the start and end range of the motion between the involved and uninvolved leg. The ratios (peak torque, total work, and average power) of the involved (IN) to the uninvolved (UN) leg were expressed as a percentage (IN/UN×100). For hypothesis testing, alpha was set at 0.05.

Results

During the study period, 315 potentially eligible patients with sciatica symptoms and signs were admitted to the Rheumatology Department. Eighty-two cases (25%) met the inclusion criteria of the study. Two hundred and thirty-three patients were excluded from the study for the following reasons: previous lumbar surgery (28%), co-morbidity (27%), duration of pain (26%), age (16%), diagnosis for radicular symptoms not confirmed at first evaluation (12%), language (11%), and refusal to participate (2%). Patients could have more than one reason for exclusion, and therefore the total adds to more than 100%.

Nine patients (11%) discontinued the study. One patient moved away from the area and eight individuals did not wish to continue. This figure compares favorably with the 16.3% rate at 3 months reported by Patrick et al. [26]. A total of 73 patients completed the study.

Patient characteristics

Two-thirds ($n=54/82$) of the patients were men, the mean age of the total population was 43 (± 10.3) years, and the mean body mass index (BMI) was 26.4 (± 4.1) kg/m². Smokers accounted for 55%, and 77% of the subjects were married. The mean duration of sciatica pain was 32 days. There were 43 patients categorized with an L5 root syndrome and 39 patients with an S1 root syndrome. Sixty-one patients were rated by the radiologist as having a disc herniation based on CT scan or MRI, and 51 patients had a positive EMG at the first visit [5].

Clinical evaluation

For the purpose of this paper, only limp, toe walk, heel walk, and manual muscle testing are reported from the standardized clinical testing over five visits (Table 1). A detailed description of clinical recovery over 1 year was published elsewhere by Balagué et al. [5].

Manual muscle testing

Muscle weakness (<4 on a scale of 0–5) tested by manual muscle testing and consistent with L5 or S1 root lesions

Peak Torque Dorsal Flexion

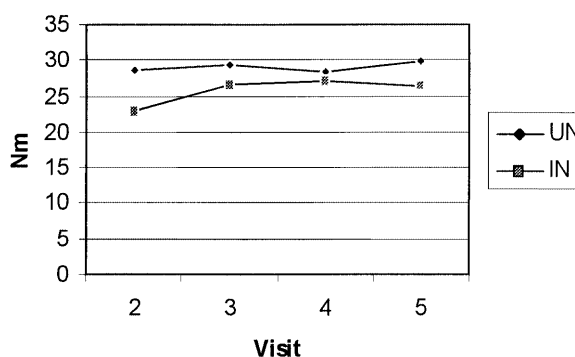


Fig. 1 Isokinetic testing [peak torque (Nm)] for the involved (IN) and uninvolved (UN) leg in patients ($n=43$) with sciatica (L5 syndrome) at discharge, 3, 6, and 12 months (visits 2–5)

Table 3 Percentage of patients with an involved leg:uninvolved leg ratio of isokinetic muscle performance (peak torque and total work) of 0.85 or less. Isokinetic testing was performed at 30°/s and 120°/s, at discharge, and at 3, 6, and 12 months (visits 2–5). For visit 5, the mean (SD) involved over uninvolved leg ratio is also displayed (*PKT 30D* peak torque at 30°/s for dorsiflexion, *TW 30D* total work at 30°/s for dorsiflexion, *PKT 30P* peak torque at 30°/s for plantar flexion, *TW 30P* total work at 30°/s for plantar flexion – same labelling for testing at 120°/s)

	Visit 2 ($n=80$)	Visit 3 ($n=69$)	Visit 4 ($n=69$)	Visit 5 ($n=71$)	Visit 5 mean ratio (SD)
PKT 30D	48%	35%	26%	34%	0.67 (0.15)
TW 30D	63%	35%	29%	37%	0.68 (0.16)
PKT 30P	65%	45%	39%	38%	0.66 (0.18)
TW 30P	60%	48%	41%	39%	0.62 (0.19)
PKT 120D	49%	32%	32%	32%	0.68 (0.15)
TW 120D	45%	32%	33%	32%	0.64 (0.18)
PKT 120P	79%	45%	51%	39%	0.66 (0.16)
TW 120P	69%	48%	45%	45%	0.62 (0.20)

was found in 15% of patients ($n=12$) at baseline, and in 5% of patients ($n=4$) at discharge. Only 1/73 patients had residual muscle weakness, evaluated by manual muscle testing, at the 1-year follow-up (Table 1).

Isokinetic muscle testing

At discharge from the hospital, more than 50% of the patients had measurable isokinetic muscle performance deficit, defined by a ratio (<0.85) of involved over uninvolved ankle muscles for either plantar or dorsiflexion at the two measured velocities. Table 2 describes recovery expressed as a ratio in percent of the involved over the uninvolved leg from discharge (visit 2), 3 months (visit 3), 6 months (visit 4), and 1 year follow-up (visit 5). Figure 1, which shows the recovery of patients with L5 syndrome,

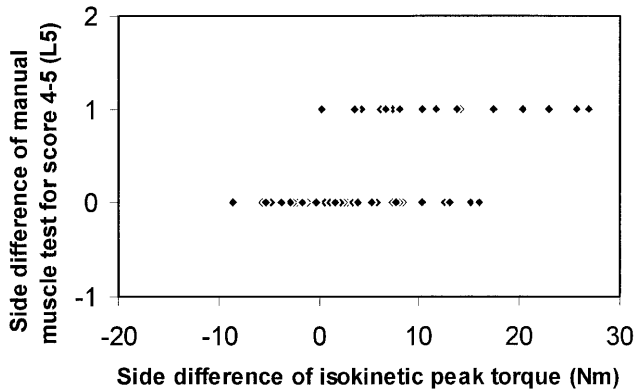


Fig. 2 Side difference (uninvolved vs involved leg) of isokinetic peak torque in Newton meters (*x*-axis) plotted against side difference of manual muscle test for score 4-5 (L5) (*y*-axis) for L5 symptomatology

reveals that a majority of patients who recover do so within the first 3 months. Approximately one-third of the patients did not fully recover their isokinetic muscle performance within 1 year as per our definition, expressed as a ratio of involved over uninvolved ankle muscles <0.85 .

As reported in Table 3, the prevalence of isokinetic muscle weakness ranged from 45% to 78% (according to the variable considered) at visit 2. At visit 5, the same values ranged from 32% to 45%.

Figure 2 demonstrates a comparison between manual muscle testing and isokinetic testing for patients with L5 syndrome as an example. The *y*-axis represents the side difference in the manual muscle testing, ranging from 0 to 1. The *x*-axis shows the isokinetic side difference for each patient with L5 syndrome, displayed in Newton meters, ranging from 0 to 30 Nm. Figure 2 demonstrates that for each value of manual muscle test, a large range of isokinetic values can be assumed. Therefore, a given value of manual muscle test difference can not be associated with a given isokinetic value, and these values can not be correlated.

Discussion

Characteristics of patients with acute severe sciatica

The characteristics of the patients participating in this study were similar to those reported in other studies, with respect to age, gender, and recollection of a precipitating event of sciatica [4, 5, 9, 17, 18, 19, 27, 31].

Muscle performance

We characterized muscle performance through two techniques, manual muscle testing and isokinetic muscle performance measurements. In isokinetic muscle testing in normal individuals, a difference between two sides of up to 15% is considered to be within normal limits [23]. Con-

sequently, we defined a ratio of the involved to uninvolved limb of less than 0.85 as indicating a muscle performance deficit in the involved limb. Ninety-five percent of patients had recovered on manual isometric muscle testing by 3 months. Isokinetic testing indicated that 30–50% of the patients (depending on the parameter under investigation) did not fully recover endurance and strength of the ankle flexor and extensor muscles of the involved leg (Table 3). For those who did not recover, the ratio (involved over uninvolved ankle performance) was approximately 0.65 for peak torque and total work at 30°/s and 120°/s.

Manual muscle testing may identify important muscle deficits, but it does not appear to be as sensitive to the smaller deficits, as measured in the isokinetic test. However, the two tests are not comparable [21]. The limited value and validity of manual muscle testing on muscle performance issues for patients with scores of 4 and higher has already been highlighted in the literature [12, 16, 25]. Dvir [12] states that “elbow and knee muscles assessed as having a score of 4 may generate as low as 10% of their maximal isokinetic strength”. Among “neuropathic patients,” Andersen and Jakobsen [3] reported that “manual muscle testing resulted in a significant underestimation of the frequency and severity of muscle weakness in both the ankle and the knee.” In their study, ankle plantar flexors were the muscles most frequently misclassified by manual testing [3]. Merlini et al. [22] reported that, for the same manual muscle testing grade, the corresponding values of isokinetic force were “very different”. Our study supports these findings.

In an effort to better understand the resolution of manual muscle testing, particularly for scores 4 to 5, we plotted the side difference of the scoring of manual muscle testing against isokinetic testing of peak torque at 30°/s (Fig. 2). The figure shows that a difference in manual muscle testing score of 4 or 5 is represented by a torque value ranging from 0 Nm up to 30 Nm. The manual muscle test is an excellent screening test for gross differences between uninvolved and involved limbs, but the limitation of the manual test scores 4 and 5 should be recognized.

Muscle performance recovery time

Most patients who recovered muscle performance did so within 3 months after hospital discharge. Knowledge that motor function recovery takes place within the first 3–4 months is valuable to both patients and physicians.

Isokinetic testing at different velocities

We chose to test at two velocities: 30°/s and 120°/s. The slow velocity is quasi-dynamic, and could be compared to static muscle testing. Fugl-Meyer et al. [15] showed a Pearson’s correlation of 0.92 between static and isokinetic

plantar flexion peak torques at 30°/s. The faster velocity was chosen, as it represents push-off velocity in moderate walking.

Patients were able complete both the slow and the fast isokinetic testing at the time of their evaluation. Pain was not a predominant factor for patients in the study, which is perhaps due to the position chosen, i.e., side lying, as well as the fact that the acute phase was over and the patients had received treatment for the sciatica pain. The patients were not prescribed pain-killers prior to or after the isokinetic muscle testing.

Future considerations

Overall, the muscle recovery results should be confirmed by other studies with a careful monitoring of range of motion. Mean total range of motion differences between the involved and uninvolved ankle motion ranged from 4.5° to 0.1°. Range of motion was plotted against peak torque and total work to inspect for any pattern or relationships. There were none to be found. The start and end range of motion in the motion cycle were also explored, and showed even fewer differences between the two sides. These differences are minor from a clinical and physiological standpoint for the outcome measures chosen in this study. We are confident that these minor differences will not change the overall results. However, from a methodological standpoint, standardization is needed to better understand the effect of the length tension curve of a muscle impairment due to sciatica. The newer isokinetic protocols should be used in future studies where the range of motion is locked and predetermined according to the involved leg [28].

Based on our results, we suggest that patients who engage in physically demanding work or active sports should be tested more carefully for strength and endurance to identify muscle performance deficits. Studies

of larger numbers of patients are needed to elaborate our understanding of the relationship between isokinetic measurements and functional testing; furthermore, it will be important to study the efficacy of different treatment protocols to improve muscle performance after severe sciatica.

Conclusions

To our knowledge, this is the first prospective study of muscle performance recovery in patients with conservatively treated severe sciatica. The primary purposes of this study were to describe the presentation and recovery of muscle deficit associated with severe sciatica and to examine the value of commonly used muscle tests. Most patients with a muscle deficit recover within approximately 3 months; however, about one-third of the patients have a muscle performance deficiency. This deficiency may not be detectable with a manual muscle test, but will show on more elaborate tests, including, for example, isokinetic testing at different velocities.

The recovery of muscle performance by manual and isokinetic muscle tests exhibits different chronologies. Therefore, further studies are needed to evaluate other functional tests in patients with sciatica. We are suggesting that isokinetic testing is a valuable functional tool in patients with demanding work or leisure tasks or in those who simply complain about their level of function. Muscle performance should be evaluated more thoroughly in these patients, who may recover fully if put on a focused rehabilitation program.

Acknowledgements We are grateful to Ms. Fabienne Sallin for her active and enthusiastic participation in the planning and organization of this study. We thank Angela Lis for her excellent help with the literature search. We are grateful to all participating patients for enduring five tests over 1 year. We thank the Reicher Foundation, Hospital for Joint Diseases, Mount Sinai NYU Health, New York, NY, USA for financial support.

References

- Albeck MJ (1996) A critical assessment of clinical diagnosis of disc herniation in patients with monoradicular sciatica. *Acta Neurochir (Wien)* 138: 40–44
- Andersson GBJ, Deyo RA (1996) History and physical examination in patients with herniated lumbar discs. *Spine* 21:10S-18S
- Andersen H, Jakobsen J (1997) A comparative study of isokinetic dynamometry and manual muscle testing of ankle dorsal and plantar flexors and knee extensors and flexors. *Eur Neurol* 37:239–242
- Atlas SJ, Deyo RA, Keller RB, et al (1996) The Maine lumbar spine study. II. 1-year outcomes of surgical and nonsurgical management of sciatica. *Spine* 21:1777–1786
- Balagué F, Nordin M, Sheikzadeh A, Echegoyen AC, Brisby H, Hoogewood HM, Fredman P, Skovron ML (1999) Recovery of severe sciatica. *Spine* 24: 2516–2524
- Bush K, Cowan N, Katz DE, Gishen P (1992) The natural history of sciatica associated with disc pathology. A prospective study with clinical and independent radiologic follow-up. *Spine* 17:1205–1212
- Campello M, Weiser S, van Doorn JW, Nordin M (1998) Approaches to improve the outcome of patients with delayed recovery. In: Nordin M, Cedraschi C, Vischer TL(eds) *New approaches to the low back pain patient*. Baillere's clinical rheumatology, international practice and research. Harcourt Brace Jovanovich, London, pp 93–113
- Cherkin DC, Deyo RA (1993) Nonsurgical hospitalization for low-back pain. Is it necessary? *Spine* 18:1728–1735

9. Debatisse D, Desfontaines P, Selak I, Maassen D, Raket D, Hotermans JM, Guerit JM (1994) L'apport diagnostique et pronostique des potentiels évoqués somesthésiques par stimulation tronculaire et dermatomale dans les conflits disco-radiculaires lombaires. *Rev Neurol (Paris)* 150:222–228
10. Deyo RA, Loeser JD, Bigos SJ (1990) Herniated lumbar intervertebral disk. *Ann Intern Med* 112:598–603
11. Deyo RA, Haselkorn J, Hoffman R, Kent DL (1994) Designing studies of diagnostic tests for low back pain or radiculopathy. *Spine* 19:2057S–2065S
12. Dvir Z (1997) Grade 4 in manual muscle testing: the problem with submaximal strength assessment. *Clin Rehabil* 11:36–41
13. Ellenberg MR, Ross ML, Honet JC, Schwartz M, Chodoroff G, Enochs S (1993) Prospective evaluation of the course of disc herniations in patients with proven radiculopathy. *Arch Phys Med Rehabil* 74:3–8
14. Fairbank JCT, Couper J, Davies JB, O'Brien JP (1980) The Oswestry Low Back Pain Disability Questionnaire. *Physiotherapy* 66:271–273
15. Fugl-Meyer AR, Gustafsson L, Burstedt Y (1980) Isokinetic and static plantar flexion characteristics. *Eur J Appl Physiol* 45:221–234
16. Griffin JW, McClure MH, Bertorini TE (1986) Sequential isokinetic and manual muscle testing in patients with neuromuscular disease. A pilot study. *Phys Ther* 66:32–35
17. Herron LD, Turner J (1985) Patient selection for lumbar laminectomy and discectomy with a revised objective rating system. *Clin Orthop* 199:145–152
18. Jonsson B, Stromqvist B (1995) Motor affliction of the L5 nerve root in lumbar nerve root compression syndromes. *Spine* 20:2012–2015
19. Junge A, Frohlich M, Ahrens S, Hasenbring M, Sandler A, Grob D, Dvorak J (1996) Predictors of bad and good outcome of lumbar spine surgery. A prospective clinical study with 2 years' follow-up. *Spine* 21:1056–1065
20. Kendall HO, Kendall FP (1974) *Muscles: testing and functions*. Williams & Wilkins, Baltimore
21. Kroemer KHE, Marras WS, McGlotlin JD, McIntyre DR, Nordin M (1990) On the measurement of human strength. *Int J Ind Ergonomics* 6:199–210
22. Merlini L, Dell'Accio D, Holzl A, Granata C (1992) Isokinetic muscle testing (IMT) in neuromuscular diseases. Preliminary report. *Neuromuscul Disord* 2:201–207
23. Morris-Chatta R, Buchner DM, de Laet BJ, Cress ME, Wagner EH (1994) Isokinetic testing of ankle strength in older adults: Assessment of inter-rater reliability and stability of strength over six months. *Arch Phys Med Rehabil* 75:1213–1216
24. Nordin M, Skovron ML, Hiebert R, Weiser S, Brisson PM, Campello M, Harwood K, Crane M, Lewis S (1997) Early predictors of delayed return to work in patients with low back pain [The Woodbridge Award for Excellence in Research]. *J Musculoskeletal Pain* 5:5–27
25. Noreau L, Vachon J (1998) Comparison of three methods to assess muscular strength in individuals with spinal cord injury. *Spinal Cord* 36:716–723
26. Patrick DL, Deyo RA, Atlas SJ, Singer DE, Chapin A, Keller RB (1995) Assessing health-related quality of life in patients with sciatica. *Spine* 20:1899–1909
27. Saal JA, Saal JS (1989) Nonoperative treatment of herniated lumbar intervertebral disc with radiculopathy. An outcome study. *Spine* 14:431–437
28. Sapega AA (1990) Muscle performance evaluation in orthopaedic practice. *J Bone Joint Surg Am* 72:1562–1574
29. Spitzer WO, Leblanc FE, Dupuis M, Abenhaim L, Bélanger AY, Bloch R, Bombardier C, Cruess RL, Drouin G, Duval-Hesler N, Laflamme J, Lamoureux G, Nachemson A, Pagé JJ, Rossignol M, Rachid Salmi L, Salois-Arsenault S, Suissa S, Wood-Dauphinée S (1987) Scientific monograph to the assessment and management of activity-related spinal disorders. *Spine* 7:S7–S59
30. Weber H (1983) Lumbar disc herniation. A controlled, prospective study with ten years of observation. *Spine* 8:131–140
31. Weber H (1994) Spine update. The natural history of disc herniation and the influence of intervention. *Spine* 19:2234–2238
32. Wood-Dauphine S, Williams JI (1991) The Spitzer Quality of Life Index: its performance as a measure. In: Osaba D (eds) *The effect of cancer on quality of life*. CRS Press, Montreal, pp 169–184