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Contribution of Neuromuscular Impairment to Physical Functional Status in Patients with Lumbar Spinal Stenosis

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ABSTRACT. ***Objective.*** To evaluate the relationship between neuromuscular impairment and physical functional status in patients with lumbar spinal stenosis.

Methods. Cross sectional analysis of 217 consecutive patients with lumbar spinal stenosis referred to 3 teaching hospitals. Physical functional status was measured with the physical dimension of the Sickness Impact Profile (P-SIP). Physical and radiological findings were abstracted from clinical records. The neuromuscular findings included pin sensation, strength, deep tendon reflexes and vibration. They were aggregated in a neuromuscular impairment index (NMI). Univariate relationships of the P-SIP and the NMI were analyzed with nonparametric methods. The determinants of physical functional status were evaluated using multiple linear regression models.

Results. In 148 patients with complete clinical data, objective weakness of the lower extremity as measured at rest was not related to physical functional status in univariate analyses. Decreased vibration was common and was associated with balance disturbance and reduced physical functional status, reflecting the importance of proprioception loss. In the multivariate regression analysis, neuromuscular deficit explained only 2.5% of the variance in physical functional status. The primary determinants of physical functional status were pain, depression, comorbid conditions and work status.

Conclusion. While neuromuscular impairment is an indispensable feature of the diagnostic evaluation, its value in assessing outcome is limited. The decision whether to intervene surgically in patients without cauda equina syndrome or rapidly progressive neurological deficits should therefore be driven by pain and physical disability rather than the degree of neuromuscular impairment. (*J Rheumatol 1994;***21:1338–43**)

Key Indexing Terms:
LUMBAR SPINAL STENOSIS
PHYSICAL FUNCTIONAL STATUS
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SICKNESS IMPACT PROFILE

Degenerative lumbar stenosis results from chronic compression of the cauda equina and the exiting nerve roots by a combination of degenerative change in the facet joints, intervertebral discs and ligamentum flavum, and is a common cause of discomfort and reduced physical functional status in the elderly. This condition is now the most common diagnosis leading to lumbar spinal surgery in adults older than 65[1] and the associated inpatient costs have been estimated to reach half-billion dollars annually in the United States[2].

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The diagnosis is based on the clinical syndrome of neurogenic claudication, generally defined as radiating pain in the buttocks and lower extremities, which is provoked by standing or walking and is relieved by lumbar flexion, along with radiological evidence of spinal stenosis with cauda equina compression[1].

Neuromuscular deficits are common in patients with longstanding symptoms. Nonoperative treatment with corsets, analgesics, nonsteroidal antiinflammatory agents, epidural corticosteroid injections and physical therapy may occasionally ameliorate or relieve the pain, but many patients do not respond to these measures and are candidates for decompressive surgery.

There is agreement that cauda equina syndrome and rapid progression of neurological deficits are indications for surgery[3-5]. However, these phenomena occur rarely in patients with spinal stenosis[6]. In the majority of patients, the progression of neurological deficits is insidious and the efficacy of decompression in preventing progression of neurological impairment has been questioned[7].

Our goal was thus to evaluate the contribution of neuromuscular impairment to physical functional disability, the disease dimension of most concern to the patient and the primary endpoint generally used to evaluate the success of surgical decompression. We hypothesized that neuromuscular deficit correlates poorly with physical functional disability and that the principal determinants of physical disability include pain, depression and sociodemographic factors, and only to a lesser extent neuromuscular impairment.

MATERIALS AND METHODS

Design. The association between neuromuscular impairment and physical functional status, along with the evaluation of the principal determinants of physical functional status, were examined in a cross sectional study of patients with spinal stenosis referred for surgery to 3 teaching hospitals.

Patients. Consecutive patients referred to the 5 study surgeons for evaluation of spinal stenosis were eligible. Inclusion criteria were age greater than 50 (to exclude predominantly congenital stenosis), presence of pain in the low back, buttock and lower extremity exacerbated by lumbar extension, and evidence of central or central lateral compression of the cauda equina by a degenerative lesion of the facet joint, disc, or ligamentum flavum on computerized axial tomography, magnetic resonance imaging or myelography. Patients unable to complete questionnaires because of cognitive or language difficulties were excluded.

Data collection procedures. The Sickness Impact Profile (SIP)[8], and data on disease specific symptoms, depression and sociodemographic variables were gathered using mailed questionnaires and augmented by phone interviews. Neuromuscular impairment, radiographic findings and the presence of comorbid conditions were abstracted from medical records using standardized coding forms. The surgeons used a protocolized examination procedure as part of their involvement in the study, ensuring fairly uniform data recording.

Measures. Physical functional status was assessed with the physical dimension of the SIP (P-SIP), a widely used quality of life measure which has been tested for its reliability and validity. The physical dimension of the SIP consists of 3 subscales measuring mobility, ambulation and body care and management. The SIP has been previously used in studies of acute[9] and chronic low back pain[10].

The symptom questions had Likert response scales and asked about overall pain, pain in the back, pain in the leg, numbness, weakness, balance disturbance, walking difficulty and walking distance. Patient characteristics included age, sex, work, living status and educational level. Depression was assessed with the Zung self-rated depression scale[11]. Comorbidity was assessed with the Cumulative Illness Rating Scale proposed and validated by Linn and Linn[12].

The physical findings abstracted from clinical records included pin sensation of the medial and lateral leg and foot, strength of the quadriceps, tibialis anterior, extensor hallucis longus, gastrocnemius, deep tendon reflexes of the knee and ankle, and vibration (recorded only for the medial foot). For purposes of the analysis we created a simple summation index for the neuromuscular findings (Table 2). Each of the eleven physical findings was graded as normal (0 point), reduced (1 point) or absent (2 points) resulting in a worst possible neuromuscular impairment index (NMI) score of 44 (22 each side).

The number of stenotic segments and the presence and degree of spondylolisthesis were abstracted from radiology reports. In 11 patients, the precise number of segments involved and degree of spondylolisthesis could not be obtained although they had reportedly radiological involvement.

Analysis. The principal dependent variable, P-SIP score, was skewed towards higher (worse) physical functional status; thus, we used nonparametric methods for the univariate analysis of relationships between P-SIP and covariates. Univariate relationships between P-SIP and specific symptoms were analyzed with the Spearman correlation coefficient. Univariate associations between P-SIP and discrete variables with 2 or 3 categories were evaluated using the Wilcoxon rank sum test and the Kruskal-Wallis test, respectively. Relationships among covariates were assessed similarly. Fisher's exact test was used for the comparison of categorical variables. The reported p values are all 2-tailed.

The determinants of physical functional status were evaluated using multiple linear regression models including both sociodemographic and disease specific variables. In our cross sectional approach, this analysis was exploratory and the directionality with respect to cause and effect could not be inferred for most variables. Only patients with a complete neurological examination were included in this analysis. The sociodemographic variables included age, sex, work status, educational level and Zung depression scale. Disease specific variables included the NMI, number of segments involved and presence of spondylolisthesis, duration of disease and pain. The model also controlled for comorbidity. Neurogenic claudication, race and prior back surgery were not included since virtually all patients had neurogenic claudication, were white and had no prior back surgery. Missing information on covariates (18% of the depression scores; less then 5% for the other covariates) were substituted with mean values. For the regression analysis we used a square root transformation of the outcome variable (P-SIP) to account for skewness towards higher scores. A second analysis using the untransformed variable revealed virtually identical results.

RESULTS

Subjects. The demographic, clinical and radiographic characteristics of the 217 patients studied are shown in Tables 1, 2, and 3.

Sixty-two percent of this elderly population with a median age of 69.6 years had significant comorbidity (score > 2). The mean (standard deviation) of the Zung depression scale was 2.0 (0.45), which represents moderate depression. The mean P-SIP score was 16.5 (range 0–55) which is comparable to the physical functional status of patients with hip osteoarthritis prior to total hip replacement surgery (mean score 17)[13]. Twenty-eight percent of the patients were working (50% of the patients under 65), 43.9% had an educational level of high school or higher, 73.4% lived with others whereas 26.6% lived alone.

The median disease duration was 18 months; the duration was > 36 months in 25% and < 9 months in 25%. Seventy-eight percent of the patients experienced severe or very severe pain and two thirds reported balance disturbance. Patients'

Table 1. *Baseline demographic variables, comorbidity index and physical dimension of SIP*

	Number (N = 217)	%
Age group (years)		
50–62	51	23.5
62–69	57	26.3
69–76	63	29.0
76–90	46	21.2
Sex		
Female	135	62.2
Male	82	37.8
Comorbidity score		
≤ 2	85	39.2
2–4	60	27.6
4–6	53	24.4
>6	19	8.8
P-SIP score		
≤ 7	51	23.5
7–14	60	27.6
14–21	44	20.3
>21	62	28.6

Table 2. *Clinical symptoms and radiographic findings*

	Number	%
Neurogenic claudication (N = 189)		
Absent	7	3.7
Present	182	96.3
Pain in back, buttock and legs (N = 215)		
Mild, very mild, none	9	4.2
Moderate	39	18.1
Severe	114	53.0
Very severe	53	24.7
Balance disturbance (N = 208)		
Never	71	34.1
Sometimes	97	46.6
Often	40	19.2
Walking distance (N = 216)		
> 2 miles	12	5.6
< 2 miles, but > 2 blocks	78	36.1
< 2 blocks but > 50′	78	36.1
< 50′	48	22.2
Difficulty walking (N = 159)		
None	7	4.4
Mild	16	10.1
Moderate	54	34.0
Severe	65	40.9
Very severe	17	10.7
Numbness or tingling in legs or feet (N = 159)		
None	38	23.9
Mild	34	21.4
Moderate	49	30.8
Severe	29	18.2
Very severe	9	5.7
Weakness in legs or feet (N = 157)		
None	20	12.7
Mild	45	28.7
Moderate	60	38.2
Severe	28	17.8
Very severe	4	2.5
Number of segments involved radiologically (N = 206)		
1	43	20.9
2	69	33.5
3	58	28.2
4 or 5	36	17.5
Spondylolisthesis (≥ 5 mm) (N = 206)		
Absent	135	65.5
Present	71	34.5

Table 3. *Neurological findings and neuromuscular impairment index*

Neurological Examination (N = 148)	Right % Diminished or Absent	Left % Diminished or Absent
Strength		
M. quadriceps	4.1	3.4
M. tibialis anterior	6.1	8.8
M. extensor hallucis longus	12.8	20.9
M. gastrocnemius	6.1	4.8
Pin prick sensibility		
Lateral leg	4.7	6.1
Medial leg	3.4	4.7
Lateral foot	5.4	4.7
Medial foot	12.2	7.4
Reflexes		
Patellar	66.2	64.8
Ankle	96.6	96.6
Vibration		
Medial foot	86.4	86.4
Neuromuscular impairment index (score)	**Number**	**%**
≤ 4	31	20.9
4–8	59	39.9
8–12	37	25.0
> 12	21	14.2

walking distance was limited to less than 2 blocks in 58%. While 71% had normal strength by examination, only 13% of the patients perceived no weakness. Spondylolisthesis of at least 5 mm was found in 34.5% of the patients and 43% had involvement of 3 or more stenotic segments.

With respect to neuromuscular impairment we report on 148 out of 217 patients with complete examination data. The demographic and disease specific characteristics of the patients with complete examination and the patients without were similar. The first group (N = 147) was on average 69 years old, 63.5% female and had a mean comorbidity score of 3.4 and a mean P-SIP score of 17.0. Severe or very severe pain was reported in 78.7%, radiological involvement of 3 or more levels was found in 48.3% and spondylolisthesis in 32.9%. The second group (N = 69) was on average 69 years old, 63.5% female and had a mean comorbidity score of 3.2 and a mean P-SIP score of 15.3. Severe or very severe pain was reported in 75.3%, radiological involvement of 3 or more levels was found in 39.7% and spondylolisthesis in 38.1%.

In the patients with complete examination data, vibratory sensation and reflexes were more commonly impaired than pin-prick sensation or strength. Ankle reflexes were absent bilaterally in 64.4% of patients, and were either reduced or absent on at least one side in 96.4%. Reduction in patellar tendon reflexes was detected in two-thirds of the patients.

Univariate associations (Table 4). The relationships between the covariates, the P-SIP and the neuromuscular index are shown in Table 4. Age, sex, work status and depression score were significant correlates of P-SIP, whereas higher education and living status (living alone) were not significantly associated with P-SIP in the univariate analysis. Comorbidity was a strong correlate of P-SIP. Overall pain (r = 0.40) was more strongly correlated with P-SIP than back pain (r = 0.25) and leg pain (r = 0.13). Walking distance, walking difficulty and balance disturbance were strong correlates of the P-SIP. A weak but significant relationship was found for self-perceived weakness whereas numbness was not related to P-SIP.

Table 4. *Univariate relationship between the covariates and P-SIP and neuromuscular impairment index*

Categorical Variables	Neuromuscular Index (N = 148) Mean	p Value*	P-SIP (N = 217) Mean	p Value*
Sex				
Female	8.7	0.36	18.5	<0.01
Male	9.5		13.3	
Work status				
Not working	9.0	0.85	18.8	<0.01
Part/full-time	9.2		11.0	
Balance disturbance				
None	7.9	<0.01	11.6	<0.01
Sometimes	8.6		16.4	
Often	11.6		25.9	
Spondylolisthesis				
None	8.7	0.6	16.4	0.71
Present	9.1		17.0	
Continuous and interval variables	**Spearman r**	**p Value**	**Spearman r**	**p Value**
Age	0.28	<0.01	0.23	<0.01
Comorbidity score	0.26	<0.01	0.36	<0.01
Disease duration	0.04	0.61	−0.04	0.6
Depression score	0.09	0.31	0.48	<0.01
Segments involved	0.10	0.25	−0.04	0.55
Pain overall	0.12	0.15	0.40	<0.01
Back pain	<0.01	0.99	0.25	<0.01
Leg pain	0.09	0.37	0.13	0.10
Numbness	0.10	0.28	0.04	0.62
Subjective weakness	0.26	<0.01	0.24	<0.01
Walk distance	0.16	0.05	0.47	<0.01
Neuromuscular index	NA	NA	0.21	0.01

NA = not applicable.
* Wilcoxon rank sum test for dichotomous, Kruskal-Wallis test for ordinal variables.

The neuromuscular index was significantly but weakly related to the P-SIP. Among the components of the neuromuscular index, patellar tendon reflexes and vibratory sensation had a significant relationship with the P-SIP. Reduced ankle reflex was not related to P-SIP. Neither pin-prick sensation, nor muscle weakness were related to physical functional status. The number of stenotic segments and spondylolisthesis were not related to P-SIP and showed no relationship with pain, neuromusuclar impairment or the sociodemographic variables.

Univariate analysis showed no correlation between subjective and objective weakness. Balance disturbance was significantly related to vibration ($r = 0.25$) and reflex deficit ($r = 0.18$).

Multivariate model (Table 5). The multivariate model which included sociodemographic variables, depression score, disease duration, neuromuscular index and anatomical variables explained 40% of the total variation of physical functional status measured with the P-SIP. The NMI which explained 5.4% of the variance in P-SIP in the univariate analysis, remained a significant independent correlate in the multivariate model explaining 2.5% of the total variation in P-SIP. In the stepwise forward selection process, pain was selected first and explained 18.7% of the variance of P-SIP, comorbidity explained an additional 8.4%, work status 4.8%, depression 3.8%, neuromuscular impairment 2.5% and sex 1.5%. Age, a significant univariate correlate was not independently associated with the P-SIP in the linear regression model. Higher education, living status (living alone), longer disease duration, greater number of segments involved and the presence of spondylolisthesis were not related to physical functional status, in either univariate or multivariate analyses.

Table 5. *Parameter estimates of the regression model. Dependent variable is physical SIP-score (N = 148)*

Variable	Parameter Estimate*	95% Confidence Interval	p Value**	Partial $r^{2\dagger}$
Intercept	−1.9			
Age (years)	0.1	(−0.1, 0.3)	0.73	<0.01
Female gender	2.6	(−1.0, 6.2)	0.06	0.015
Education	1.8	(−1.7, 5.3)	0.35	<0.01
Living alone	1.0	(−3.1, 5.1)	0.44	<0.01
Working	−5.3	(−9.2, −1.4)	<0.01	0.048
Comorbidity score	1.0	(0.2, 1.8)	<0.01	0.084
Pain	4.4	(2.1, 6.7)	<0.01	0.187
Depression score	6.3	(1.9, 10.7)	0.01	0.038
Disease duration (months)	0	(−0.1, 0.1)	0.97	<0.01
Neuromuscular impairment score	0.4	(0.0, 0.8)	0.03	0.025
Segments involved	0.1	(−1.6, 1.8)	0.77	<0.01
Spondylolisthesis	0.27	(−3.3, 3.8)	0.64	<0.01

** p Values from the model with the square root of P-SIP.
* Parameter estimates from the model with P-SIP.
† Partial r^2's from the forward selection process.
Model $r^2 = 0.40$; F-Test for the model: < 0.01.

Based on the parameter estimates of this model, the predicted difference in the physical SIP score between a patient having the median observed neuromusuclar impairment score (8 points, representing for example bilateral absence of vibration and extensor hallucis longus) and a patient having minimal deficit (1 point, representing e.g., unilateral reduced vibration) was 3.3 points. In contrast, the predicted difference in P-SIP between patients with very severe pain and patients with moderate pain was 8.8 points.

To put these differences in perspective, the mean P-SIP score in our sample was 16.5 points and the mean change in P-SIP score following laminectomy in patients with spinal stenosis was 6.5 points (Katz JN, unpublished data). Thus, 8.8 points represents an enormous difference and a 3.5 point difference is modest.

DISCUSSION

Patients referred with spinal stenosis experience considerable physical disability. However, the degree of objective neuromuscular impairment explains a relatively small amount of the variation in physical functional status and is reminiscent of the weak relationship between physical signs and reported disability in patients with nonspecific low back pain[14].

Consistent with previously reported series, objective muscle weakness is not common[15-17]. This may be explained in part by the multiple segmental innervation of most muscles. The preservation of strength is also hypothesized to result from effective reinnervation by collateral sprouting of surviving motor units[18]. This compensation is effective until 50–70% of the motor units are lost[18]. It is, however, important to note, that neuromuscular testing was performed when patients were at rest in our study. Testing after exertion may reveal more frequent and severe strength deficits[19]. Interestingly, self-perceived weakness, which measures subjective weakness with exertion, was correlated significantly with reported physical functional status while objective muscle testing was not. This finding suggests that testing of neuromuscular impairment may be more informative if it is performed after exertion.

Pin-prick sensitivity deficits were uncommon compared with vibration deficits which were noted in 86.9% of the patients. This has been noted anecdotally but has not been well documented in the literature. Also, vibratory deficit was a strong correlate of self-reported balance disturbance. Balance is multifactorial and relates to strength, proprioception and, particularly in patients with spinal stenosis, to sway of the center of gravity[20]. Our data suggest, that vibration deficit and, to an even greater extent, balance disturbance are important correlates of perceived physical functional status.

Reduction in reflexes was a common finding in our patients with the patellar tendon reflex involved in as many as two thirds of patients. The greater physical disability in patients with deficits of patellar tendon reflexes may reflect the involvement of L3/L4 in addition to L5/S1.

The degree of anatomical impairment, as shown by imaging studies, was not related to physical functional status at all. Although radiological stenosis is indispensable in confirming the clinical diagnosis and planning surgical intervention, the number of stenotic segments involved and the presence and extent of spondylolisthesis are of little value in assessing the impact of the disease on the patient.

In a comprehensive multivariable model, neuromuscular impairment was a significant but weak correlate of functional physical status. The strongest correlate of physical functional status was pain. Back pain and leg pain were independently associated with physical functional status. Depression was found to be a strong correlate of physical functional status in the model. Work status was an independent correlate of physical functional status and may be a surrogate for prognostically favorable social and psychologic factors. However, in a cross sectional analysis it is difficult to determine whether depression and work status represent cause, effect, or as we suspect, both. As previously noted, women referred for surgery have worse physical functional status (Katz JN, unpublished data). This may reflect referral bias, reporting bias or sex differences in preferences for surgical therapy. Women were similar to men with respect to neuromuscular impairment, anatomical and sociodemographic variables. However, women reported significantly more pain.

Some limitations of the study require comment. First, the study population consists of patients referred for consideration of surgical decompression and therefore represents the severe end of the disease spectrum. Second, neuromuscular impairment data were collected by chart abstraction using physician notes. However, the surgeons utilized a protocolized examination procedure as part of their involvement in the study, ensuring fairly uniform data recording. Of more concern is the problem of missing values for neuromuscular data. However, patients with complete neuromuscular data did not differ from the group without complete physical examination data with respect to baseline characteristics (i.e., sex, age, disease specific symptoms and functional physical status). To assess deep sensitivity loss, vibratory sense was recorded and served as a surrogate of joint position sense which may be more directly relevant for balance disturbance and physical function. Furthermore, in the elderly study population, vibration and reflexes may be impaired for reasons other than the studied disease process. This may explain, why neuromuscular deficit explained an even smaller amount of the variation in physical functional disability in a multivariate analysis controlling for age and comorbidity than in the univariate analysis. Also, electrodiagnostic tests were not available to document the extent of nerve compression: they were not performed routinely but only for differential diagnostic reasons, since it was felt that the additional information would not justify costs and burden for the patient. Finally, the assessment of anatomical impairment was based on radiology reports and included just two variables, spondylolisthesis and number of segments involved. The reports were unlikely to introduce bias, as radiologists were unaware of this study. In addition, there is no validated classification and grading system for radiologic evaluation of spinal stenosis available. However, a more detailed assessment of radiographic nerve compression might have shown an association with disease impact.

In conclusion we found that the neurological exam and anatomical involvement, as performed in our study, were not important correlates of reported physical functional status in patients with lumbar spinal stenosis. While they are indispensable features of the diagnostic evaluation, their value in assessing outcome is limited. The decision of whether to intervene surgically in patients without cauda equina syndrome or rapidly progressive neurological deficits should therefore be driven by pain and physical disability rather than the degree of neuromuscular impairment.

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