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ORIGINAL ARTICLE

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A prospective study of the interrelationship between subjective and objective measures of disability before and 2 months after lumbar decompression surgery for disc herniation

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Abstract The value of range of motion (ROM) as an indicator of impairment associated with spinal problems, and in monitoring changes in response to treatment, is a controversial issue. The aim of this study was to examine the interrelationship between subjective disability (Roland-Morris scores) and objectively measured impairment (ROM), both before and in response to spinal decompression surgery, in an older group of patients with herniated lumbar disc (DH). Seventy-six individuals took part in the study: 33 patients (mean age 57 years, SD 9 years) presenting with DH and for whom decompression surgery was planned, and 43 controls (mean age 57 years, SD 7 years), with no history of back pain requiring medical treatment. In the patient group, pain intensity (leg and back; visual analog score), self-rated disability (Roland-Morris score), certain psychological attributes, and ROM of the spine (Spinal Mouse) were measured before and 2 months after decompression surgery. In addition, the patients rated the success of surgery on a 1–5 Likert scale. The pain-free control group performed only the tests of spinal mobility. Before surgery, compared with matched controls, significantly lower values were observed in the DH patients for standing lumbar lordosis ($p = 0.01$), and for range of flexion of the lumbar spine (ROF_{lumbar}) ($p = 0.0006$), but not of the hips (ROF_{hip}) ($p = 0.14$). Roland-Morris Disability scores correlated significantly with ROF_{lumbar} ($r = 0.61$, $p = 0.0002$), but less well with ROF_{hip}($r = 0.43$, $p = 0.01$). Two months after surgery, there were significant reductions in back pain and leg pain ($p = 0.0001$) and in Roland-Morris Disability scores ($p = 0.019$). There was also a significant decrease in the group mean values for lumbar lordosis angle (i.e., a "flatter" spine after surgery, $p = 0.002$) and ROF_{lumbar} ($p = 0.038$). ROF_{hip} showed a (non-significant) tendency to increase ($p = 0.08$) towards normal control values. As a result of these two opposing changes, the range of total trunk flexion showed no significant changes from pre-surgery to 2 months post-surgery ($p = 0.60$). On an individual basis, there was a highly significant relationship between the change in self-rated disability scores and the change in ROF_{lumbar}, pre-surgery- to 2 months post-surgery ($r = -0.82$; $p < 0.0001$). Changes in ROF_{hip} showed no such relationship ($r = -0.30$, $p = 0.10$). The patients in the "poor" outcome group ("surgery didn't help"; 9%) had a significantly greater reduction in ROF_{lumbar} post-surgery compared with the "good" outcome group ("surgery helped"; 91%) ($p = 0.04$). In stepwise linear regression, the change in ROF_{lumbar} was the only variable accounting for the change in self-rated disability pre-surgery to post-surgery (variables *not* included: pain intensity, psychological factors). The pivotal role of lumbar mobility in explaining disability emphasizes the importance of measuring lumbar and hip ranges of motion separately, as opposed to "global trunk motion." In the patient group examined, the determination of lumbar spinal mobility provides a valid, objective measure of function, that shows differences from normal matched controls, that correlates well with self-rated disability, and the changes in which correlate extremely well with subjective changes in disability following surgery.

Keywords Spinal mobility · Lumbar range of motion · Herniated disc · Spinal decompression surgery · Roland-Morris Disability · Outcome

Introduction

The important distinction between physical impairment (defined as objective structural/physiological limitation) and disability (the resulting loss of function) has been highlighted by a number of authors [35, 41, 57]. Disability is a good clinical assessment of severity in low back disorders (70). One might expect that an individual's disability would be strongly determined by his/her level of physical impairment, as it is in other joint complaints. However, in the case of low back pain (LBP) the relationship between these two variables is often complicated. This may be the result of the confounding influence of various cognitive and affective factors on self-ratings of disability, or a consequence of insufficient unequivocal methods for assessing physical impairment.

Painful disorders and injuries of the spine commonly result in dysfunctions of motion, manifest as either restrictions in global movement capacity or aberrant segmental movements [45, 49, 54]. Range of motion (ROM) of the lumbar spine is currently the only measure included in popular published guidelines for the assessment of impairment associated with low back pain [3]. As such, measures of ROM are frequently employed as the main objective outcome criterion in quantifying the effects of various treatments for back pain [11, 18, 23, 28, 32, 51]. Nonetheless, the value of objective measures of spinal mobility in assessing dysfunction and in monitoring changes following treatment remains a highly controversial issue within the spine research community.

It has been suggested that self-report questionnaires of disability are of greater relevance in assessing the severity of the back problem or the outcome after treatment than are so-called objective measures of impairment, such as ROM [14]. Self-rated disability reflects not only the patient's actual physical (structural or physiological) incapacity but also their (sometimes erroneous) perception of their disability, which itself is known to be influenced by a number of negative psychological attributes [33, 55]. As these same psychological factors also determine whether the patient rates a given treatment as successful, or deems himself capable of resuming employment/needing further treatment—the gold standard criteria often used to assess the utility of various surrogate measures—it seems natural that self-reports of disability will correlate better with these gold-standard measures than will objective measures of impairment alone.

A recent systematic review of studies investigating the correlation between lumbar ROM scores and spinal disability and function reported that the results were "inconclusive" [49]. Most commonly, if any relationship was seen at all, the coefficients of correlation ranged between just 0.3 and 0.5, indicating that, within a group of patients, the variation in ROM measures accounted for a meagre 9–25% of the variance in self-rated disability. Notably, many of the studies included in the review had been carried out on patients with chronic, nonspecific LBP, for whom the relationship between subjective and objective measures may intuitively be expected to be less than optimal.

In the search for valid objective indices of impairment, it is possible that ROM measures may not be the unique or ultimate solution for the assessment of *all* spinal problems, but may still have a decisive role to play with regard to specific diagnoses in which restrictions in movement are typically a major feature of the clinical picture.

The aim of the present study was to examine the relationship between objectively measured impairment and subjectively measured disability in a group of patients ($>$45 years old) diagnosed with lumbar disc herniation (DH) due to undergo decompression surgery. Firstly, in a baseline cross-sectional analysis, spinal ROM of DH patients before surgery was compared with that of matched controls. Further, in the DH patient group, the correlation between spinal ROM and self-rated disability (Roland-Morris scores) was examined. Then, in a prospective manner, the relationship between individual changes in these objective (ROM) and subjective (Roland-Morris scores) measures, pre-surgery to post-surgery, was determined. In each case, using regression analysis, the relative influence of the ROM measures in explaining the variance in Roland-Morris scores was examined in relation to the influence of psychological and pain characteristics, in order to identify the variables of greatest importance in explaining self-rated disability in this patient group.

Methods

Overview of study

The study group comprised patients diagnosed with lumbar disc herniation who were referred to the hospital's spine unit, and for whom decompression surgery without fusion was foreseen (patient details appear below). Baseline questionnaires and functional assessments of spinal mobility were carried out 1–2 days before the operation and repeated at the first post-surgical checkup, 2 months after the operation.

All patients received an oral and written explanation of what would be required of them, and they signed an informed consent form confirming their agreement to participate. The study was approved by the local university's ethics committee.

Study admission criteria

The admission criteria were:

- Age over 45 years (an inclusion criteria for a larger study in which the patients were participating on rehabilitation after surgery for degenerative spinal stenosis and disc herniation in older patients)
- No previous spinal fusion (although other previous spine operations were permitted)
- Failed conservative therapy
- Diagnosis of lumbar herniated disc as the main indication for decompression surgery

In all patients, the medical history was taken, a clinical examination was performed, and conventional radiography of the lumbar spine as well as MRI and/or CT was carried out to confirm the encroachment of the spinal canal. The herniated levels were distributed as follows: L1/2, one patient (3%); L2/3, one patient (3%); L3/4, four patients (12%); L4/5, 20 patients (61%); and L5/S1, seven patients (21%).

Study group

The original group included 37 patients. However, due to time constraints before the operation, two patients were unable to complete the preoperative functional tests, and a further two did not undergo postoperative tests (one lived in another country and could not return for tests, but completed a questionnaire; a second required re-operation with spinal fixation within the first 2 months). Thus, 33 patients had complete data sets (24 men, nine women), both pre-surgery and post-surgery. Their mean age was 57 years (SD: 9 years). The mean duration of low back trouble before the operation was 4.7 years (SD: 8.1 years), and of leg pain, 2.5 years (SD 5.6 years). The patients had been receiving medical attention for their back-related problems for an average 3.2 years (SD: 6.5 years). Thus, they represented a group with specific symptoms of a herniated disc deemed to require surgery, superimposed on a long-term (degenerative) back problem. Fifty-five percent of the patients declared that leg pain was their greatest problem, 20% back pain, 15% sensory disturbances (numbness, tingling, etc.) and 10% other factors (e.g., buttock pain; combined back, leg and buttock pain). The individual visual analog scores (VAS) for leg and back pain revealed that, even in those patients for whom back pain was perceived to be the greater problem, the levels of leg pain were only slightly less—i.e., substantial leg pain was reported by all patients, even if it was not always the greatest problem. The high proportion of patients with leg pain *and* back pain was attributed to the accompanying degenerative changes of the spine in this relatively old patient group.

For comparative purposes, a group of 43 healthy volunteers (26 men, 17 women) over 45 years of age (mean age 57 years—SD: 7 years), with no history of any back pain requiring medical treatment or time off work, underwent assessment of spinal mobility, in order to provide age-matched control values. There was a slightly higher proportion of females in the control group than in the patient group, but the difference was not significant ($p = 0.33$).

Surgical procedure

Decompression surgery involved a posterior midline approach to the laminae. The spinal canal was entered by removal of the ligamentum flavum. Laminotomy of the caudal and rostral laminae and, if necessary, partial medial facetectomy, was carried out. The herniated mass/extruded nucleus pulposus was exposed and extracted.

Assessments: questionnaires

Pre-surgery, patients were sent a comprehensive questionnaire (see below), which they were asked to complete in their own time and bring with them on the day of admission to the hospital. A second questionnaire was sent out in a similar manner, shortly before the patient's first checkup (approximately 2 months post-surgery).

The questionnaire enquired about:

- Socio-demographic variables, work status, workload, reason for deciding to undergo surgery

- Existing or planned disability/compensation claims
- Back/leg trouble history (duration, previous operations, etc.)
- Pain location (pain drawing)
- Pain intensity (0–10 VAS for: average back pain in the last week; average leg pain in the last week; back-related pain at best in the last week, at worst in the last week, and today)
- Frequency of back/leg trouble (never (0), occasionally (1), often (2), constant (3))
- Frequency of pain medication intake
- Low back disability (Roland-Morris Disability Questionnaire [13, 46])
- Beliefs about physical/work activity being a cause of back trouble and fears about the dangers of such activities when experiencing an episode of low back pain (Fear-Avoidance Beliefs Questionnaire (FABQ) [59])
- ‘‘Psychological disturbance’’ [19] (determined using a combination score from the modified somatic perception questionnaire (MSPQ [30]) and the modified ZUNG questionnaire [31])

All the questionnaires had been previously validated in the German language [32, 48].

Post-surgery, the patients were asked to rate the success of the operation (0, made things worse; 1, didn’t help; 2, only helped a little; 3, helped; 4, helped a lot).

Considering that the patients were undergoing relatively major elective surgery, for which a notable change in symptoms was to be expected, only scores of 3 and 4 were considered a ‘‘good’’ global outcome, whilst 0, 1 and 2 were considered ‘‘poor.’’

Assessments—spinal mobility

All tests of spinal mobility were carried out at least 2 h after the patients/subjects had got up in the morning. This was done to overcome the initial stiffness of the spine associated with the increased fluid absorbed by the intervertebral discs while they are unloaded during the recumbency of sleep [27]. Spinal mobility was assessed using the Spinal Mouse system (Idiag, Switzerland), a computer-assisted electronic inclinometer device that can be used to measure spinal curvature in the sagittal plane, in various postures (Fig. 1). The intra-tester and inter-tester, and day-to-day reliability of the Spinal Mouse has been published in previous studies [25, 34], in which further details about the system are also given [34]. Briefly, the device is guided along the spine, slightly paravertebrally, from a start position at the spinous process of C7 to an end position at S3. These bony landmarks are firstly determined by palpation and marked on the skin surface. A rolling sensor head follows the contour of the spine and communicates distance and angle measures to a base station interfaced with a personal computer. This information is then used to calculate the relative positions of the sacrum and the vertebral bodies of the underlying body spinal column, using an intelligent, recursive algorithm.

Measurements were made in each of the following postures:

- Standing upright (in a relaxed position, focusing on a marker placed at eye level, feet shoulder-width apart, knees straight, arms at sides)
- Maximal flexion (legs straight, trunk flexed as far as comfortably possible in an attempt to curl the head into the knees, hands gripping the back of the lower leg for stability, if necessary)
- Maximal extension (legs straight, arms crossed over the front of the body, head in a neutral position, trunk extended as far as comfortably possible)

The positions were described and demonstrated by the investigator, and then each movement sequence (standing, flexion, extension) was performed by the patient three times. The patient was instructed to move at a speed of his/her choosing and to hold the end position for about 3 s, whilst the measurement was made. The best two trials (judged in relation to the total trunk flexion attained)—in the majority of cases, the last two of the three—were averaged for use in further analyses (as described in [34]). The patients were instructed to move as far as they possibly could without causing intolerable pain. Pain intensity (in the back and/or legs) during each of the three postures was recorded on a 0–10 VAS.

The relevant parameters recorded by the Spinal Mouse in each position were: lumbar curvature (measured from the T12/L1 interspace to the L5/S1 interspace), sacral angle (with respect to the vertical) and trunk angle of inclination (angle subtended between the vertical and a line joining T1 to the sacrum). Determination of these parameters in standing, full-flexion and full-extension positions allowed calculation of the ranges of flexion (ROF) and extension (ROE) of the ‘‘hips’’ (sacral angle), the lumbar spine, and the whole trunk (in each case, the ROF and ROE were given by the difference between the standing value and the value in the flexed or extended position, respectively).

Statistics

The sample size calculations for both the prospective study (changes after surgery) and the comparison of the DH patients with normal controls were based on the results of our previous reliability study [29, 34]. We calculated that, with at least 30 patients in each group, the probability would be 95% that the study would

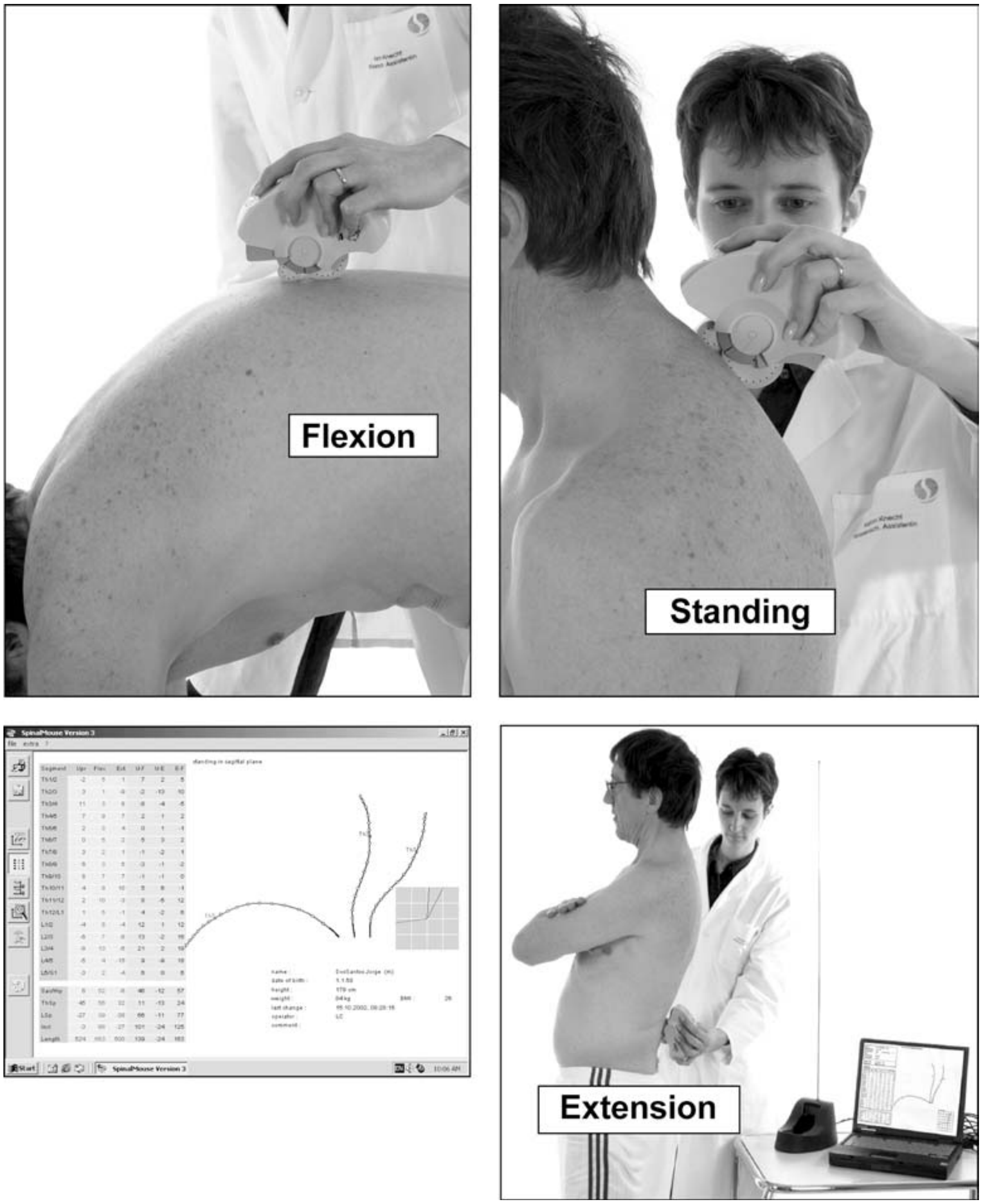

Fig. 1 Equipment used for measuring spinal range of motion. See text for details

detect a significant difference between the two groups of interest at a two-sided 5.0% significance level, if the true difference between them for the range of flexion of the lumbar spine was at least 9°.

The ROM data and disability data were all approximately normally distributed and so parametric statistical analyses were used. Differences in ROM between the patients and the normal controls were examined using unpaired Student *t*-tests (any interaction between the pattern of difference between the groups, in men and women, was firstly examined by looking at the interaction term (group *x* gender) of a repeated-measures analysis of variance (ANOVA)—one between factor (gender) and one within factor (time of test, i.e., pre-surgery or post-surgery). No interactions were significant).

Changes in continuous variables, pre-surgery to post-surgery, were assessed using paired *t*-tests. Changes in categorical/ordinal variables were examined using non-parametric statistics (paired sign test or Wilcoxon signed rank test, depending on the number of categories). Relationships between continuous variables were analysed with regression analysis (simple, and then stepwise multiple regression). Differences between outcome groups (good vs poor) for changes in ROM after surgery were expressed as median values (with interquartile range, IQR) and analysed using the Mann–Whitney U-test (as the distribution of changes in ROM were not normally distributed). Significance was accepted at the 5% level.

Results

Self-rated disability and pain

The group mean (SD) values for Roland-Morris Disability, VAS pain scores, pain frequency, and pain medication intake, before and after surgery, are shown in Table 1. All the pain-related outcome measures showed highly significant improvements 2 months after surgery (each $p<0.001$). Roland-Morris Disability scores showed a somewhat lesser, but nonetheless significant reduction after surgery ($p=0.019$).

Spinal curvature/ranges of motion

The group mean (SD) values for spinal curvature and ranges of motion, before and 2 months after surgery are shown in Table 2, together with the data for age-matched controls with healthy backs.

Before surgery, the herniated disc patients demonstrated a significantly lower lumbar lordosis in standing compared with the controls (i.e., they had a flatter back) ($p=0.01$). In addition, their lumbar range of flexion (ROF_{lumbar}) and trunk ROF (ROF_{trunk}) were significantly reduced compared with normal values (both $p<0.004$). The difference between patients and controls for hip ROF (ROF_{hip}) narrowly failed to reach significance ($p=0.15$). All these trends were the same for both men and women. None of the ranges of extension, for any region of the spine, were significantly different from control values, though there was a general tendency for them to be lower.

Two months after surgery, the mean standing lumbar lordosis showed a further significant reduction (i.e., flatter spine after surgery, $p=0.002$) (Table 2) and the mean ROF_{lumbar} was significantly lower ($p=0.038$) than before surgery. There was a trend for an increase in ROF_{hip} after surgery ($p=0.08$), which was nonsignificant but of a sufficient extent to mean that the postoperative values for this parameter became very similar to those of the controls (see Table 2). The combination of the decreased ROF_{lumbar} and increased ROF_{hip} meant that the global ROF_{trunk} did not change significantly pre-surgery to post-surgery ($p=0.75$). Again, all these trends were consistent for both men and women—i.e., there were no significant interaction effects for gender and measurement time (pre-surgery/post-surgery).

None of the values for range of extension, for any regions, showed any significant change compared with pre-surgery values.

Back/leg pain intensity during the flexion test (measured on a 0–10 VAS scale) was significantly correlated with ROF_{lumbar} ($r=0.56$, $p=0.001$). Also, the changes (from before surgery to 2 months after surgery) in VAS back/leg pain during the flexion test and in ROF_{lumbar} were significantly correlated ($r=0.56$, $p=0.001$). However, more than half of the patients who experienced no pain at all during the flexion test post-surgery (10/19; 53%) still had a reduced ROF_{lumbar} (of 4–33°), suggesting that it was not simply pain that was responsible for the reduction in lumbar mobility 2 months after surgery.

Table 1 Self-rated pain and disability before and 2 months after surgery. All values are means (SD) (*VAS* visual analog scale)

Parameter	Before surgery	2 months after surgery	*p*
Roland Morris Disability score	12.7 (6.3)	9.9 (6.2)	0.019
VAS back pain—average (over the last week)	4.1 (2.9)	2.2 (2.1)	0.001
VAS leg pain—average (over the last week)	5.7 (2.4)	1.9 (2.2)	0.0001
VAS pain (back or leg)—highest (over the last week)	7.3 (2.1)	3.2 (2.6)	0.0001
VAS pain (back or leg)—lowest (over the last week)	3.6 (2.4)	1.1 (1.5)	0.0001
VAS pain (back or leg)—today	5.0 (2.5)	1.9 (2.1)	0.0001
Pain frequency*	2.4 (0.8)	1.4 (0.9)	0.0001
Pain medication*	0.4 (0.5)	0.1 (0.3)	0.0001

*Presented as continuous data (possible scores 0 (best) to 3 (worst)) for ease of presentation, but non-parametric test statistics used to test statistical significance of pre-surgical vs post-surgical data

Relationships between objective and subjective measures of disability: pre-surgery

Using bivariate regression analyses, the values for the following objective ROM measures (from all those listed in Table 2) showed a significant correlation with the Roland-Morris scores pre-surgery: ROF_{lumbar} ($r=0.61$, $p=0.0002$), ROF_{trunk} ($r=0.54$, $p=0.004$); ROF_{hip} ($r=0.43$, $p=0.01$); ROE_{lumbar} ($r=0.57$, $p=0.0005$); ROE_{trunk} ($r=0.61$, $p=0.0002$).

The following psychological factors also correlated significantly with the Roland-Morris scores at baseline: "psychological disturbance" ($r=0.56$, $p=0.0008$); fear avoidance beliefs about physical activity ($r=0.57$, $p=0.0005$). Similarly, most of the pain scores correlated with Roland-Morris Disability: VAS average back pain ($r=0.44$, $p=0.01$), VAS average leg pain ($r=0.41$, $p=0.01$), VAS highest back/leg pain ($r=0.69$, $p=0.0001$), VAS lowest back/leg pain ($r=0.39$, $p=0.026$).

As Roland-Morris Disability correlated both with the various ROMs and with the psychological factors, it was

Table 2 Standing lumbar lordosis and spinal mobility in controls and disc herniation (DH) patients before and 2 months after surgery. All values are means (SD) (*ROF* range of flexion, *ROE* range of extension)

Parameter (°)	Controls ($n = 43$)	Patients before surgery ($n = 33$)	Patients 2 months after surgery ($n = 33$)	–
Lumbar lordosis	30.6 (10.2)	24.8 (8.5)	21.1(7.1)	a, b, c
Hip ROF	47.7 (13.6)	42.1 (18.9)	47.2 (16.6)	–
Trunk ROF	100.2 (18.3)	84.7 (27.1)	85.9 (29.0)	a, c
Lumbar ROF	54.6 (12.5)	42.8 (15.9)	36.7 (13.1)	a, b, c
Hip ROE	17.0 (11.0)	13.4 (8.9)	13.8 (8.6)	–
Trunk ROE	25.4 (11.0)	22.8 (10.3)	21.9 (11.3)	–
Lumbar ROE	6.8 (10.1)	6.9 (5.6)	6.7 (6.7)	–

a = Significant difference ($p < 0.05$) between controls and patients before surgery
b = Significant difference ($p < 0.05$) in the patients before and after surgery
c = Significant difference ($p < 0.05$) between controls and patients after surgery. In each case, the data from the men and women were analyzed together; there was no significant gender effect for the manner in which controls and patients differed in any of the analyses

considered of interest to see whether the psychological factors, *per se*, were associated with range of motion. To account for the possible shared variance, partial correlation analysis was used (with the variables range of motion, psychological variables and Roland-Morris Disability). It was shown that the partial correlations between the psychological variables and ROF_{lumbar} were negligible and nonsignificant (with FABQ, partial $r = -0.15$; with psychological disturbance, partial $r = -0.19$). The psychological factors had a slightly greater, but still negligible and nonsignificant correlation with ROF_{trunk} (with FABQ, partial $r = -0.14$; with psychological disturbance, partial $r = -0.31$) and with ROF_{hip} (with FABQ, partial $r = -0.10$; with psychological disturbance, partial $r = -0.31$).

As a number of the variables were clearly interrelated, multiple stepwise regression analysis was carried out, in order to identify which of the main domains (ROM, psychological factors, pain intensity) still contributed significantly to explaining the variance in Roland-Morris scores, when considered together with the other domains. For this analysis, only the one variable from each domain that had the highest correlation with the Roland-Morris scores in the bivariate analyses was included, to reduce the number of predictor variables entered. Together, the following factors (in decreasing order of their contribution) contributed significantly to explaining a total 83% of the variance in Roland-Morris scores: VAS highest back/leg pain, fear avoidance beliefs about physical activity, and ROF_{lumbar}.

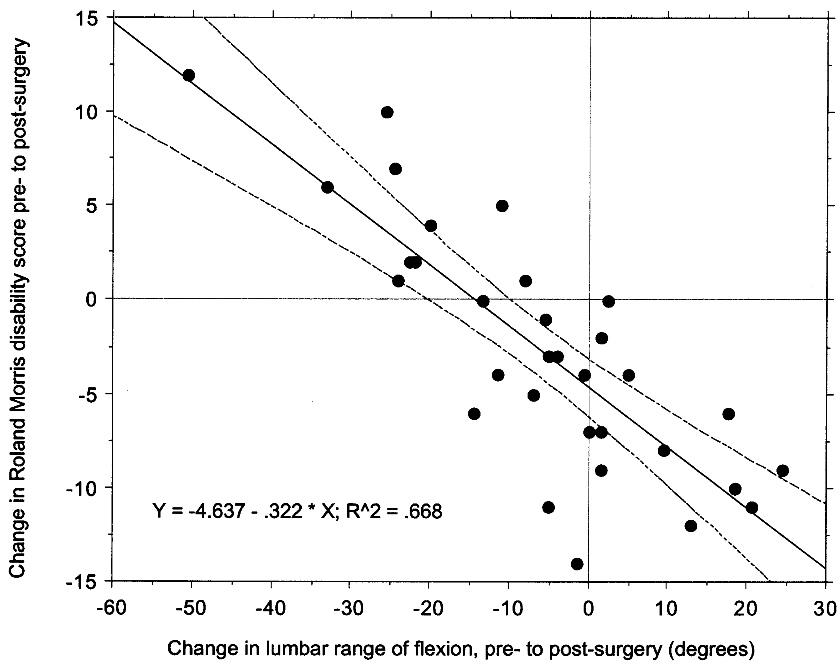

Fig. 2 Regression analysis (with 95% confidence intervals) showing the relationship between the change in lumbar range of motion and the change in Roland-Morris Disability scores, pre-surgery to post-surgery

Relationships between changes in objective and subjective measures of disability: pre-surgery to post-surgery

Using bivariate regression analyses, changes in two of the objective measures (from those listed in Table 2) showed a highly significant inverse correlation with changes in the Roland-Morris scores: ROF_{trunk} ($r = -0.59$, $p = 0.0004$), and ROF_{lumbar} ($r = -0.82$, $p = 0.0001$; Fig. 2). The greater the increase in ROF, the greater the reduction in disability (Roland-Morris score). The only subjective variables whose changes after surgery correlated with the change in disability were: VAS highest back/leg pain ($r = 0.51$, $p = 0.002$) and psychological disturbance ($r = 0.49$, $p = 0.004$).

When the most significant variables from each of the above domains (ROM, psychological factors, pain intensity) were examined together in a multivariate stepwise regression analysis, ROF_{lumbar} was the only variable that was chosen for entry into the model as a significant contributor to explaining the variance in the change in Roland-Morris scores. No further variance could be explained by changes in either the pain scores or psychological attributes. Statistically, 67% ($p < 0.0001$) of the post-surgical changes in self-rated disability were accounted for by changes in the objective measures of ROF_{lumbar}.

Global rating of surgery

Two months after surgery, 22/33 (67%) patients declared that the surgery had "helped a lot," 8/33 (26%) that it had "helped" and 3/33 (9%) that it had "not helped." No patients said that it had "only helped a little" or "made things worse." Thus, in accordance with the previously described dichotomous rating, 91% of patients had a "good" outcome and 9% a "poor" outcome.

The patients in the poor outcome group were characterized by a greater reduction in their ROF_{lumbar} after surgery (median −22.5°; IQR 1.5°) compared with the good outcome group (median 0°; IQR 22.3°) ($p = 0.04$).

Discussion

General

The present study sought to investigate the relationship between objective measures of spinal mobility and self-reports of disability in a group of patients who were due to undergo decompression surgery for lumbar disc herniation. Clinical examination had revealed suspected herniated discs in all these patients, and this was confirmed by imaging and, later, intraoperatively. However, the patients were not necessarily typical of patients presenting with an acute herniated disc. They were older than the average DH patient, and many had had pain (both leg *and* back) for a long period of time. We consider this to be the result of concomitant degenerative changes in the disc and the facet joints in these patients. Whether the findings would be replicated in a group of younger, acute disc herniation patients remains to be examined, although one might expect even closer relationships between impairment and self-rated disability in such a group, as psychological factors are likely to play less of a role than they do in patients with chronic LBP.

The study did not primarily aim to evaluate the effectiveness of the surgical procedure, *per se*, hence the short follow-up is of no particular consequence. The aim was simply to assess the relationship between subjective and objective measures, both before and in response to the surgical intervention. Nonetheless, as the operation is one that attempts to remedy a mechanical problem, its success or failure might still be expected to be apparent relatively early (i.e., after the patient has recovered from the effects of the operation itself). Furthermore, as the early results of decompression surgery often herald the longer-term findings [4, 20, 22]), a careful examination of the shorter-term outcome is still deemed worthwhile. The longer term outcome and changes in functional capacity in this patient cohort after a 3 month period of rehabilitation will be reported in detail in a separate paper. However, briefly, the excellent relationship between the change in ROF_{lumbar} from pre-surgery to 2 months post-surgery and pre-surgery to 6 months post-surgery ($r = 0.92$, $p < 0.0001$) and between the change in ROF_{lumbar} pre-surgery to 6 months post-surgery and the change in disability over the same time period ($r = 0.75$, $p < 0.0001$) suggest that the observed phenomenon is not just a consequence of circumstances peculiar to the early postoperative period.

Spinal curvature and range of motion before surgery

Pre-surgery, the group mean values for standing lumbar lordosis, and ROF_{lumbar} and ROF_{trunk} were all significantly lower than those of age- and gender-matched controls with no history of back pain that had required medical treatment. Thus, the patients had flatter and stiffer lumbar spines than normal. The controls showed mean values for ROF_{lumbar} similar to those reported in the literature for healthy individuals assessed using other skin-mounted motion analysis devices [8, 12, 34], double inclinometers [36] or X-ray measurements [44], in part confirming the validity of the measures. Whether the reduced ROF_{lumbar} can be attributed entirely to the results of the disc prolapse, or, rather, was also a factor contributing to its development in the first place, cannot be ascertained from the results of this study. Interestingly, a previous prospective risk-factor study showed that individuals with a flatter and stiffer lumbar spine (the same factors characterizing the patients in the present study) were more prone to the development of a ‘‘serious back problem’’ requiring medical treatment or time off work (though not necessarily disc herniation), than were their counterparts with a more pronounced lordosis and good lumbar flexibility [2]. A recent report from the same research group, on the outcome of the individuals that developed serious low back pain for the first time during the initial study, showed that the reduction in lumbar mobility displayed after the first episode did not improve over the subsequent 2-year period [11]. A further study, in which a marked reduction in ROF_{lumbar} was reported in disc herniation patients pre-surgery, showed that even 1 year after surgery, and following a postoperative exercise rehabilitation program, ROF_{lumbar} increased to only approximately 80% of normal values [10]. All of this would tend to suggest that disc herniation patients perhaps never had, or are rarely able to acquire, normal values for spinal mobility.

Determinants of self-rated disability before surgery

In the present group of disc herniation patients, the baseline scores for self-rated disability correlated with the objective ROM measures to a greater extent than has been shown in previous studies [21, 33, 38, 39, 40, 50, 58]. However, disability also showed a significant association with certain cognitive and affective factors. Most likely, after a long period of suffering with back trouble, these patients are in some respects similar to other groups of patients with chronic back problems, in whom self-ratings of disability appear to be influenced by a whole range of both physical and psychological attributes [33, 55]. A couple of recent reviews have clearly shown that the stress of living with chronic pain leads to depression [16, 17] and that chronic back pain is associated with exaggerated fear-avoidance beliefs about movement [56]. Hence, the relatively strong influence of the psychological factors is not wholly surprising. Interestingly, however, in comparison with recent studies on patients with chronic nonspecific LBP [33], in the present patient group the objective measures still played a substantial role in governing self-reported disability.

Relationship between changes in psychological factors and disability post-surgery

In a multivariate analysis designed to identify the factors of greatest importance in explaining the change in disability after surgery, the psychological factors were not selected for entry into the model (i.e., they added nothing to the model from a statistical point of view, once ROM had been entered). Nonetheless, in simple bivariate analyses, the changes in psychological disturbance post-surgery correlated significantly with the changes in disability. Perhaps the patients’ psychological status improved, once their pain was alleviated and their functional capacity enhanced following the operation. This would tend to support the assertion that psychological disturbance arises predominantly as a consequence of long-term pain and ineffectual treatment [16] and resolves when a successful solution to the problem has been found [52].

Relationship between changes in spinal mobility and changes in self-rated disability after surgery

The group mean ROF_{lumbar} showed a reduction 2 months after surgery, although considerable inter-individual differences in the extent of the change were observed. Further, these individual changes in ROF_{lumbar} appeared to have a strong association with both the patients’ self-rated disability and their overall satisfaction with the operation. Psychological factors, *per se*, had minimal influence on the measured ranges of motion. The results show one of the highest correlations between subjective and objective measures of disability reported in the back pain literature to date. Changes in the objective measures of ROF_{lumbar} accounted for almost 70% variance in the change in disability after treatment. There are a number of possible explanations for these findings. Firstly, the device used to measure ROM is somewhat new, and it is conceivable that the measurements are more reliable and accurate than those obtained in previous studies and are thus more sensitive to differences that may otherwise have been obscured by measurement error. However, whilst this may be so in the case of previous studies that have employed measures such as the Schober skin-stretching technique [5, 53] or the long-arm goniometer [42]—techniques with their own well-known limitations—it is unlikely to be the case for studies in which more accurate double inclinometers or computerized motion analyses devices were employed [7, 26, 58].

The second possible—and more likely—explanation is that, with the specific diagnosis of herniated disc, restrictions in ROF_{lumbar} play a more important part in the clinical picture than they do in groups of patients with nonspecific back pain. Indeed, in a previous study in which the spinal mobility of patients with nonspecific low back pain was compared with normal controls, using the same measurement technology (Spinal Mouse), the results were similar to previous findings of no significant difference between the groups [29].

Cadaveric studies have shown that flexion of the spine with a model herniated nucleus pulposus increases the compressive force and tension applied to the nerve root traversing the herniation [47]. These findings are consistent with the classical clinical observation of an increase in symptoms associated with straight-leg raising or trunk flexion. Although flexion increases the size of the spinal canal, it simultaneously increases nerve root tension [6]. Much of the improvement in movement capacity after decompression surgery is attributable to the simple freeing of the mechanical obstruction, which relieves the painful nerve root tension generated during trunk flexion movements. A previous study on patients with disc herniation showed that, after surgery, spinal movements were improved in the clinical sense—i.e., the majority of patients reported an enhanced ability to flex the trunk as a whole, and straight-leg raise values were improved—yet biplanar radiography did not confirm any significant improvement in the group's mean lumbar ROM [54]. These findings were effectively replicated in the present study. The objective measures showed improved values for hip flexion, and the patients had lower average pain and disability ratings—all despite a lower ROF_{lumbar}. Closer examination of the graph showing the relationship between changes in lumbar ROF and changes in self-rated disability after surgery (Fig. 2) reveals that the slope does not cross through the zero points of the *x* and *y* axes. At $x =$ zero (i.e., no change in ROF_{lumbar}), the intercept on the *y* axis is approximately −5 (i.e., a reduction in self-rated disability score of 5 points). At first glance, this would seem to suggest that the ROF_{lumbar} is unrelated to the clinical attributes. However, superimposed on this systematic shift was an indisputable relationship between individual changes in disability scores and changes in ROF_{lumbar}. Thus, it would appear that, after the improvement in pain and disability brought about by the surgical freeing of the mechanical obstruction (the herniated disc material), the ROF_{lumbar} is a strong determinant of the remaining disability.

The importance of lumbar range of flexion

Two questions naturally arise from the preceding discussion: firstly, why should specifically *lumbar* range of flexion determine so strongly the changes in self-rated disability; and, secondly, what accounts for the differing individual results with regard to changes in ROF_{lumbar} post-surgery? We have no immediate answers to these questions, but certain factors are worthy of consideration.

Previous studies on back-healthy individuals have shown that the lower the ROF_{lumbar}, the greater the bending moment acting on the osteoligamentous spine during standardized forward bending and lifting activities—regardless of the individual's degree of hip mobility [8]. There appears to be something uniquely important about the flexibility of the lumbar spine in governing the ability to perform such movements without undue stress. A possible explanation may lie in the findings of studies in which simultaneous spine and hip movements have been examined during free trunk flexion. These have shown that the first 60° of movement is accomplished almost exclusively [15] or predominantly [36, 43] by flexion of the lumbar spine. The addition of a load purportedly exaggerates this movement pattern, such that most of the spinal flexion has occurred by the time the trunk is inclined 45° forward from the upright position [15]. Thus, in individuals with restricted lumbar flexion, the full range would likely be required even during activities that require only moderate trunk flexion, leading to higher bending stresses in the lumbar spine [1]. These higher stresses may be associated with discomfort, especially if any of the posterior structures of the spine are also injured. In this case, attempts to adopt the positions of quite extreme lumbar flexion typically required for even some of the simplest activities of daily living [9, 24] may be unsuccessful, leading the individual to report himself disabled in these tasks.

The reasons for the widely varying individual differences in the change of ROF_{lumbar} after surgery, and the dramatic reduction in ROF_{lumbar} after surgery, are somewhat more difficult to explain. Neither psychological disturbance nor fear avoidance behaviour was able to account for the reduced ROF_{lumbar}. To the authors' knowledge, there is currently no evidence that decompression surgery *per se* (especially of the minimally destructive type employed) has a detrimental effect on the mobility of the spine, although it has also not been subject to much systematic investigation. Perhaps the extent of soft-tissue scarring after surgery in some way determines the degree of restriction during forward-bending movements. This clearly requires further investigation.

Conclusion

In conclusion, in older patients with disc herniation, the determination of lumbar spinal ROM provides a valid, objective measure of functional capacity that shows significant differences from normal matched controls, that correlates well with the patient's subjective disability rating, and the changes in which correlate extraordinarily well with changes in self-rated disability following surgery.

The pivotal role of the lumbar range of flexion in explaining the changes in disability after surgery, and the opposing changes in lumbar mobility and hip mobility after decompression surgery, emphasize the importance of measuring lumbar and hip ranges of motion separately, and caution against the use of global trunk flexibility tests (e.g., sit and reach, toe touching, etc.) in characterizing spinal functional capacity.

Previous authors have suggested that a patient's subjective rating of pain/disability is not a reliable indicator of his or her impairment (i.e., objectively measured functional capacity) 3 months after spine surgery for degenerative disorders [37]. This would seem not to be the case, at least in the diagnostic group examined in the present study and as far as measures of spinal mobility are concerned.

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