Correlation of Objective Measure of Trunk Motion and Muscle Function with Low-back Disability Ratings

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A study was undertaken to examine relations among some objective and subjective measures of low-back-related disability in a group of 41 low-back pain patients and in seven pain-free control subjects. Subjective measures of disability were obtained by Oswestry patient questionnaires. Oswestry disability score related significantly (*P* <0.001) to presence or absence of relaxation in back muscles during flexion. Mean trunk strength ratios were inversely related to disability score (*P* <.05), and trunk mobility was meaningfully reduced (*P* <.01). Despite loss of motion, a large enough excursion was observed to predict presence of back muscle relaxation. These findings imply that myoelectric signal levels, trunk strength ratios, and ranges of trunk motion may be used as objective indicators of low-back pain disability. [Key words: low-back disability, objective measurement, myoelectric signal, flexion relaxation, trunk strength and mobility]

MEANINGFUL RATINGS OF low-back-related disabilities can serve for example to contrast the effectiveness of one treatment procedure with that of another, or to establish rational criteria for disability compensation, or to return to work after a back injury. Ratings of disability probably would be more meaningful if they were based on objective measurements rather than on subjective impressions. The strongest motivation for seeking objective measurements of low-back-related disabilities is the clues those measurements might provide as to the organic sources of those disabilities. The majority of low-back impairments are still rightly classified as idiopathic.

The current study was undertaken to examine relations among some objective and subjective measures of low-back-related disability. Objective measures of ranges of trunk motions, of intra-individual ratios of lumbar trunk muscle voluntary strengths in attempted extension to those in attempted flexion, and of the presence or absence of the flexion-relaxation phenomenon in the back muscles were obtained in a group of patients with low-back pain and in a group of pain-free control subjects. Subjective measures of disability were obtained from patient questionnaires, and the objective and subjective measures were compared using the method described in this report. Intra-individual trunk strength ratios in patients with low-back pain were reported by McNeill et al[7] and Addison and Schultz.[1] McNeill et al, found 27 healthy male control subjects to have a mean ratio of voluntary strength in attempted trunk extension to that in attempted trunk flexion of 1.37, whereas 25 male patients who had low-back pain and who attended an outpatient clinic, had a mean ratio of 0.98. Addison and Schultz found 16 male patients seeking hospitalization for low-back pain to have a mean ratio of 0.92. Statistically, both measures of patient/healthy subject differences were significant.

The flexion-relaxation phenomenon refers to the diminution of myoelectric activity in the back muscles upon substantial forward bending of the trunk while standing. Schultz et al[10] reviewed inquiries into this phenomenon and reported a study in which 11 healthy male subjects all showed readily detectable flexion-relaxation even upon only 40° of lumbar trunk flexion. In two of the earlier reports on the phenomenon, Golding[4] and Floyd and Silver[3] found no relaxation of back muscle myoelectric activity upon flexion in 34 of 120 patients and 34 of 105 patients with low-back pain, respectively. Neither of these reports describes whether partial absences of the flexion-relaxation phenomenon were observed in the remaining patients.

There are a number of methods for subjective evaluation of disability due to low-back pain (Ransford et al,[8] Roland and Morris,[9] Lehman et al,[5]). In this study we used the Oswestry questionnaire because of its simplicity, internal consistency, and test-retest reliability (Fairbanks et al,[2]). Ranking of responses with respect to limitations of routine daily activities imposed by low-back pain permits calculation of a subjective "disability" score for comparison with other measures.

MATERIALS AND METHODS

Tests were performed on 19 men and 29 women whose ages ranged from 22 to 59 years (mean, 35.5). Forty-one of these subjects complained of low-back pain with or without leg pain, and seven served as control subjects (Table 1). Patients were recruited from a population attending a clinic for evaluation and treatment of low-back and/or leg pain restricted to L3-S1 dermatomal distribution. The population was a heterogeneous mixture of patients with pain. Pain interval ranged from 2 days to 1.86 years (mean 271 days). Patients with clinical evidence of scoliosis, muscular weakness or atrophy, sensory loss, altered deep tendon reflexes, or pain distribution in other than L3-S1 dermatomes were excluded. Control subjects were recruited as volunteers who had no clinical evidence of scoliosis and no history of significant low-back pain during the 6 months prior to testing.

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Table 1. Data for Subjects Tested and Their Oswestry Scores

Subject	Age (yrs)	Height (cm)	Weight (kg)	Symptom time (days)	Oswestry score
1	43	177	94	4	35
2	28	165	71	180	13
3	35	171	73	42	26
4	33	159	49	120	17
5	23	163	60	95	21
6	42	155	46	21	21
7	46	181	100	2	1
8	59	163	61	21	31
9	44	177	79	14	24
10	30	150	48	10	27
11	45	182	87	35	15
12	51	177	79	9	36
13	36	170	63	10	10
14	36	170	64	90	20
15	41	171	77	60	6
16	23	166	66	90	23
17	42	161	45	240	12
18	22	188	83	62	2
19	43	177	93	45	2
20	31	166	70	1,195	3
21	27	155	53	7	2
22	33	159	56	127	4
23	41	155	49	240	8
24	35	164	69	150	13
25	28	188	109	1,440	8
26	24	184	77	300	11
27	31	165	52	7	11
28	44	160	50	90	16
29	47	182	92	3,600	2
30	30	150	47	17	12
31	25	178	76	2	3
32	27	187	72	6	0
33	28	178	115	14	4
34	32	152	45	10	5
35	29	178	68	3	1
36	44	169	63	7	6
37	23	172	64	240	1
38	52	171	105	17	12
39	52	171	105	22	4
40	25	169	70	1,095	6
41	25	168	72	1,101	3

The Oswestry Disability Questionnaire (Fairbanks et al,[2]) was completed by each patient to provide a subjective rating of limitation in performance of daily tasks. The Oswestry Disability Questionnaire consists of ten questions on ability to perform common activities of daily living. The maximum of 50 points would be scored by patients with disabilities severe enough to require that they remain bedridden, whereas a patient with no disabilities at all would score zero points. Location of pain distribution was solicited by asking each patient to categorize his or he discomfort as being in the low-back, leg, or combined low-back and leg pain.

The range of trunk motion in standing flexion and extension was measured in each subject. An inclinometer was placed on the back at the thoracolumbar junction and the subject was asked to extend and flex the trunk as far as possible without aggravation of any pain present, while holding the knees straight. The subjects then preformed six other tasks: stand relaxed; stand with trunk flexed maximally and exert maximum voluntary strengths from the upright position, twice in attempted trunk flexion, and twice in attempted trunk extension. For purposes of the current study, full trunk flexion was measured as the maximum flexion a subject could attain without exacerbation of pain.

During performance of the standing flexion range-of-motion task and of these last six tasks, trunk muscle myoelectric activity was picked up by four pairs of bipolar surface electrodes. Two pairs were placed bilaterally on the back, over the erector spinae muscles, 3 cm from the midline at the L3 level. Two pairs were placed bilaterally over the rectus abdominus muscles, 3 cm from the midline at the umbilicus level. The raw signals from the four pairs of electrodes were amplified and stored on magnetic tape. They later were rectified and integrated over a 4-sec interval, using a .5-sec time constant.

For all tasks, subjects stood in a comfortable position within a testing frame. The pelvis was strapped to a posteriorly placed support. The knees were similarly supported by a loosely fitting strap. The maximum voluntary strength tests were conducted using a strap around the shoulders that was attached to a load cell. With the subject standing relaxed, the load cell was positioned level with the shoulder strap. Any laxity between the load cell and the strap was removed by using an adjustable chain. The subject then attempted to bend the trunk against the resistance of the load cell. Subjects were coaxed to ensure maximal force production but were instructed to cease exertion if too painful. Unless the effort was too painful, a repeat test was made. Then the load cell was repositioned and exertion force measurements were made in attempted trunk extension. To determine the intraindividual trunk muscle strength ratio, the mean force developed during the maximal efforts in attempted extension was divided by that in attempted flexion.

Patients were grouped for analysis according to the presence or absence of flexion-relaxation upon trunk bending; ie, near silence of the myoelectric signals in the back muscles. In three cases, relaxation occurred in the back muscles on one side of the spine only. These cases were included in the no-relaxation group. This analysis compared Oswestry scores, strength ratios, and motion ranges among these three groups. Two-way analysis of variance was performed for "control," "flexion-relaxation-present," and "flexion-relaxation-absent" subjects.

RESULTS

Twenty-three of the 41 patients with complaints of low-back or leg pain and all seven of the control subjects exhibited flexion-relaxation; ie, the level of myoelectric activities in their back muscles substantially diminished upon full trunk flexion. In the remaining 18 patients, flexion-relaxation was absent. Absence of flexion-relaxation was not seen in any subject who had an Oswestry score of less than 8.

Control and relaxation-present subjects showed three separate phases of back muscle myoelectric activity; while bending forward, while fully flexed as limited by pain, and while rising to the upright (Figure 1). Relaxation absence was readily identified by persistence of marked myoelectric activity during full flexion (Figure 1, Table 2). Comparison of activities in the left paraspinal muscles to those in the right during the flexion test showed symmetrical behavior for both control and relaxation-present subjects while in the fully flexed position. Relaxation-absent subjects showed an unequal response in paraspinal activity at full flexion. Larger myoelectric signals were found on the painful side in two-thirds of these subjects.

Retrospectively, cutoff values for Oswestry and trunk strength ratios were constructed from sample means plus one standard deviation. Grouping of subjects as to presence or absence of flexion-relaxation was searched for subjects falling outside these values. In four subjects, Oswestry and/or strength ratio values exceeded these cutoff points.

Table 2. Myoelectric Signal Levels in the Back Muscles During Trunk Flexion (mv)

	While bending		*Fully flexed*		*While rising*	
Subject group	*Left*	*Right*	*Left*	*Right*	*Left*	*Right*
Relaxation absent	53(24)	51(22)	51(34)	44(33)	83(50)	78(52)
Relaxation present	42(14)	39(16)	7(8)	7(8)	101(28)	94(37)
Controls	30(12)	31(14)	2(4)	2(4)	91(33)	74(32)

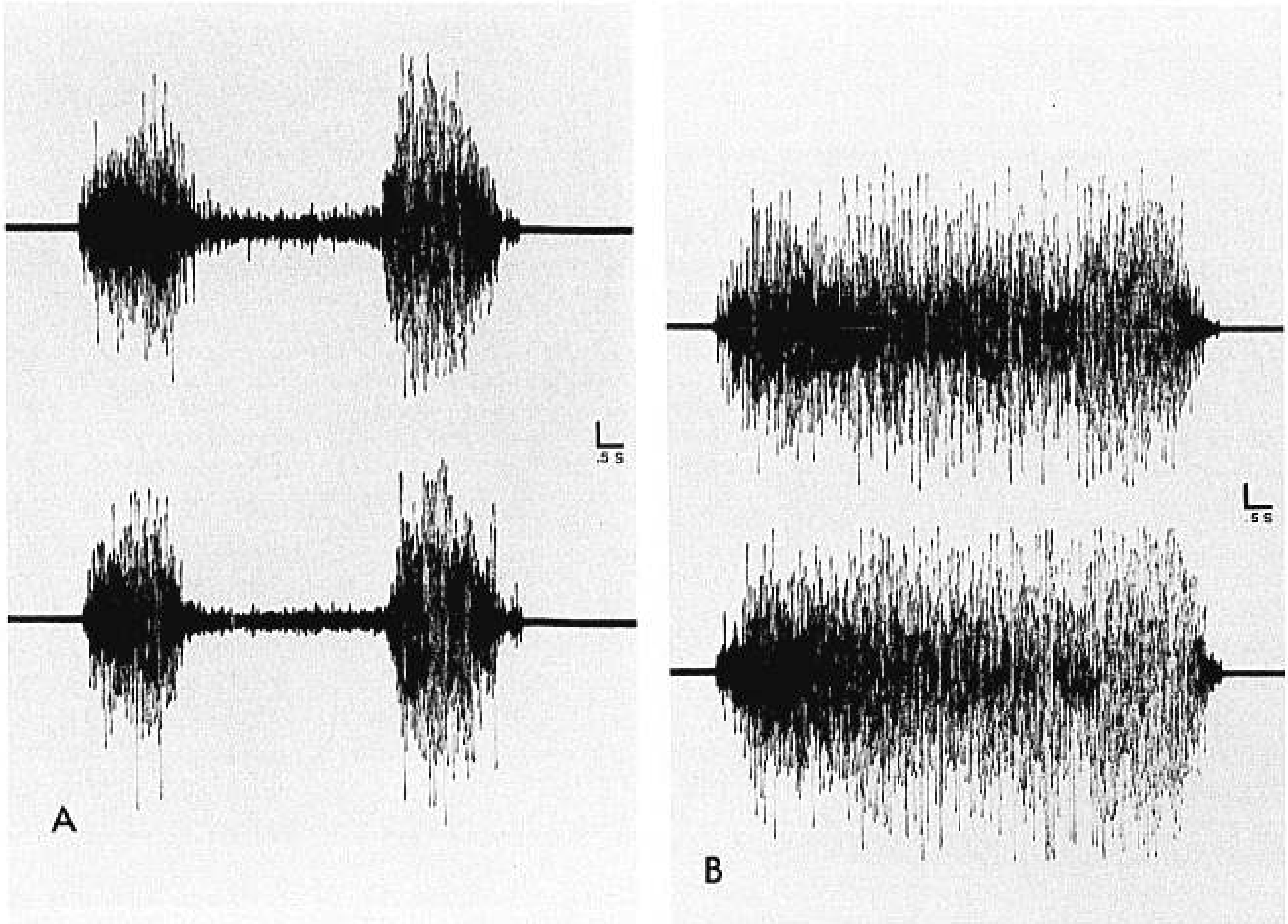

Fig 1. A, Paraspinal myoelectric activity in a control subject during flexion task. Separate phases of muscle action during bending, fully flexed, and rising to stance are clearly apparent. **B,** Paraspinal myoelectric activity in a high Oswestry test score patient during three phases of flexion task. Loss of flexion-relaxation is evident.

DISCUSSION

Presence or absence of flexion–relaxation in the paraspinal lumbar muscles, the extensor–flexor strength ratio, and the range of trunk motion corresponded approximately to the Oswestry score. These findings imply that, under conditions similar to those described here, myoelectric signal levels, trunk strength ratios, and ranges of trunk motion may be used as objective indicators of low-back pain disability.

Several reasons might be given to explain the absence of flexion–relaxation. First, relaxation of myoelectric activity during trunk flexion is dependent on the amount of flexion. Schultz et al[10] found relaxation to begin at 40° of flexion. A subject might voluntarily constain flexion to a range insufficient to produce relaxation. Review of the inclinometer measurements showed that was not the case in our study. While relaxation-absent subjects had smaller ranges of both extension and flexion compared with controls and relaxation-present subjects, all subjects flexed their trunks beyond 40°. Second, muscle contraction may persist beyond 40° of flexion as a volitional of reflexive reaction to pain. Despite instructions to cease bending at the onset of substantial pain, pain was sometimes reported during the performance.

Information obtained from the inclinometer measures are inherently limited to total motions with respect to an implied vertical reference. Subcomponents, for example, arising from the contribution of the hip could not be quantified directly. Maximally obtained flexion is some composite of intervertebral and hip motion. Whereas an attempt was made to restrict hip motion, success in doing so cannot be quantitatibly assessed. It is possible, then, for intesegmental motion to be restricted, perhaps by persistent muscle action, while a nearly complete range of flexibility to touch the toes is retained.

When the subjects were grouped as to presence or absence of flexion–relaxation, a number of differences in the collected data were found. The mean duration of symptoms in the relaxation-absence group was 61.4 days, whereas in the relaxation-present group it was 423 days. Because of the large variance, this difference was not significant.

The Oswestry disability score related significantly to the presence of relaxation. Relaxation-absent subjects had a mean score of 18.8, whereas relaxation-present subjects had a mean score of 5.76. This difference was statistically significant ($P < 0.001$). Product moment multivariant correlation (Keslinger[6]) analysis by category was performed by assigning arbitrary dummy variable values to relaxation-present and relaxation-absent categories, yielding a coefficient of .74.

Findings as to trunk strength ratios were similar. The relaxation-absent group had a mean ratio of 0.84, the relaxation-present group had a mean ratio of 1.07, and the healthy controls had a mean ratio of 1.35. Statistically, all three of the relaxation-present/relaxation-absent/control pair differences were significant ($P < .05$) with a negative correlation coefficient ($r = -.47$).

Grouping of subjects by pain distribution is shown in Table 3. Mean values for Oswestry and extension : flexion ratio tend to be more severe for those with leg complaints than for those with low-back complaints, or low-back and leg complaints. Owing to the small number of subjects with this category of complaint and the high intersubject variability, the differences are not statistically significant.

Measurements of range of motion were obtained in maximally obtained flexion and full extension for each subject (Table 4). Controls had a mean trunk extension of 33° and a mean trunk flexion of 109°. Relaxation-present subjects had a mean extension of 29° and a mean flexion of 102°. Relaxation-absent subjects had noticeably less mobility. Mean extension was 21° degrees, whereas mean flexion was 71°. Relaxation-absent/relaxation-present and relaxation-absent/control differences were significant ($P < .01$).

Table 3. Oswestry Scores and Trunk Strength Ratios for Subjects Grouped by Site of Complaint

Pain distribution	*Oswestry score*	*Trunk strength ratio*	*N*
Low back	10.5 (9.0)	1.0 (.40)	28
Leg	16.3 (11.6)	.83 (.24)	8
Low back and Leg	10.4 (8.8)	1.02 (.30)	5

Parentheses indicate standard deviations.

Table 4. Range-of-motion Data (Degrees)

	Healthy control	*Flexion–relaxation present*	*Flexion–relaxation absent*	*Significance of difference*
Extension	33 (8)	28 (8)	20 (7)	$P < .01$
Flexion	109 (12)	101 (22)	71 (27)	$P < .01$

Flexion–relaxation presence implies that the structural loads are being transmitted primarily by the ligamentous and articular passive tissues of the spine. Persistent activity, reflecting persistent muscle contractions, may serve to transmit loads through muscles rather than through injured spinal ligamentous tissues in an effort to avoid increased pain.

Attempted extension : flexion trunk muscle strength ratios also appeared to be sensitive to the degree of disability. As Oswestry scores increased, the strength ratio mean values monotonically decreased ($r = -.32$). Rarely did the presence of substantial pain associate with an extension : flexion strength ratio as large as those in control subjects. In three cases, ratio values were within one standard deviation of the control mean. Above an Oswestry score of 12, only one subject had an extension : flexion ratio greater than 1.2. Vallfors[11] reported a thorough study of idiopathic low-back pain characteristics following arbitrary classifications of pain into acute, subacute, chronic, and recurrent. As in our study, patients were categorized by pain behavior evaluations. Site of injury responsible for symptoms is often not able to be clearly ascertained. As a result, our population represents a heterogenous population of patients with low-back pain. Our findings are correlated to pain-associated restrictions in activities of daily living with primary emphasis on distribution restricted to l3–S1 dermatomes. Relationships to specific back conditions, if any, remain to be determined.

CONCLUSIONS

1. Relaxation of backmuscle myoelectric activity upon full trunk flexion was absent in all but one patient who reported low-back pain and had an Oswestry score exceeding 12. With the exception of three patients, flexion–relaxation was present with a score lower than 10.

2. The mean ratio of trunk muscle strength in attempted extension to that in attempted flexion was 1.35 in pain-free control subjects, 1.08 in patients with Oswestry scores of less than 8.5 (mean minus one standard deviation) and 0.84 in patients with Oswestry scores exceeding 10.5 (mean plus one standard deviation). This ratio correlated with the degree of clinical complaint, as either verbally reported, or quantified by the Oswestry score.

3. Persistence of paraspinal myoelectric activity at maximally

obtained flexion in patients reporting substantial pain is not a result of restricted motion. Mean flexion range was 109° in pain-free control subjects, 102° in relaxation-present patients, and 71° in relaxation-absent patients. All but three patients could flex their trunks beyond 40°, which would be enough for the presence of relaxation to have become noticeable.

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