Trunk Strengths in Patients Seeking Hospitalization for Chronic Low-Back Disorders

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Trunk strengths of 16 male and 17 female patients with chronic low-back disorders were measured. The patients sought hospitalization for four weeks in a pain clinic. Maximum voluntary trunk strengths in the standing position were measured during attempted flexion, extension, and lateral bending. The trunk strengths of these patients were then compared with those of healthy subjects and with those of patients with low-back disorders who sought treatment as outpatients of a general orthopaedic office practice. In making the comparisons, intra-individual trunk-strength ratios were used to overcome problems due to the effects of patients' general weakness and any psychologic factors. When compared with healthy subjects, the patients seeking hospitalization had significantly smaller strengths during attempted extension relative to their strengths during attempted flexion or lateral bending. Their trunk-strength ratios did not differ significantly from those of the outpatient group. [Key words: low-back pain, trunk muscle strength, voluntary isometric contraction]

THIS PAPER REPORTS maximum voluntary static trunk strengths in the standing position during attempted flexion, extension, and lateral bending for 33 patients with low-back disorders. The disabilities of these patients had disrupted their lives to such an extent that they sought four weeks of hospitalization in a low-back-pain clinic. This study is a companion to that of McNeill et al[1] which reports trunk strengths of healthy subjects and of outpatients with low-back disorders who were generally less disabled and disabled for shorter periods of time than were our patients. A main goal of the present paper was to compare the intra-individual strength ratios of the patients who sought intensive treatment in the pain clinic with those of the patients who sought treatment as out-patients in a general orthopaedic office practice.

The causes of the chronic low-back conditions of the pain-clinic patients are unknown. The patients had failed to respond adequately to previous treatment. Pain-clinic patients sometimes exhibit symptoms of neurosis and sometimes are thought to have psychogenic, rather than organic, sources of pain. Measurements of their trunk strengths provide objective data concerning their physical capabilities. By means of analyses on an intra-individual basis of the data obtained, questions of motivation and psychogenic pain factors can largely be overcome, making possible a better determination of whether an organic source of limitation of performance exists.

MATERIALS

Sixteen male and 17 female patients participated in the tests. Ten of the men and six of the women were undergoing four weeks of therapy in the Low-back Pain Clinic of the Rehabilitation Institute of Chicago; the remaining patients were undergoing a two-day program

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to evaluate their suitability for enrollment in the clinic. Suitability for enrollment in the clinic is established on the basis of significant chronic disability resulting from low-back disorders. The presence of chronic disability is determined from the medical and social histories of the patients, responses to questionnaires about daily activities and needs for medication to treat pain, and psychologic tests. The low-back disorders prevented the patients from functioning normally. The patients were usually unemployed, had histories of unsuccessful treatments that often included repeated back operations, and usually were taking narcotic medication. Alchoholism was sometimes a problem. Based on such data, the patients' overall disabilities were graded on a scale of zero (no disability) to four (complete disability). The mean general disability grade assigned was approximately two. Table 1 provides data on the disability grades and the patients ages, heights, and weights.

The trunk strengths of these patients were compared with those of subjects from two other groups, both described in detail by McNeill et al.[1] One was a group of 57 healthy subjects, free of any significant low-back disorders. The other was a group of 40 patients who sought treatment for low-back disorders in a general orthopaedic office paractice. On the average, these patients were less disabled and were disabled for shorter periods of time than were the candidates for treatment in the pain clinic. For example, the mean duration of the disorders reported by the patients from the office practice was approximately 30 months for both men and women, while the mean duration reported by the patients from the pain clinic was 73 months for the men and 44 months for the women. In addition to the grade for general disability, a grade was assigned on the basis of questionnaire results for the patients' pain at the start of the strength testing. This grade ranged from zero (no pain) to four (very severe pain). The mean pain grade at the time of testing was approximately two (see Table 1).

Table 1. Characteristics of the Healthy Subjects and the Patients from the Pain Clinic*

	Men		Women	
	Healthy subjects	*Patients*	*Healthy subjects*	*Patients*
Number	27	16	30	17
Mean age in years	33.5	41.2	31.6	36.4
Range	21–61	25–56	21–59	20–62
Mean height (cm)	177	180	165	168
Range	152–191	168–191	152–185	157–180
Mean weight (newtons)	766	792	602	704
Range	623–979	650–1015	445–881	556–845
Mean periodic of symptomatic history (months)		72.6		44.4
Range		2–216		6–276
Mean disability grade				
General disability		1.87		2.22
Pain at time of test		1.93		2.00

* Some data were not available for all subjects. In particular, heights and weights of many patients were not available, so that these figures are approximate. Data for healthy subjects are based on the report of McNeill et al.[1]

METHODS

The legs and pelvis of each patient were strapped against a padded backboard with the patient in a comfortable standing position. A harness was placed around the chest, and cables were run from this harness to force-measuring load cells. Patients were asked to pull against the cables maximally while attempting in turn flexion, extension, and left-lateral and right-lateral bending for periods of five seconds each. The tests were isometric, and little motion was allowed. Each test was carried out twice. Patients were asked about the nature and intensity of any pain experienced during the test, and this was graded on the zero-to-four scale just described.

Anthropometric measurements for each patient and consideration of the effects of lever arms were used to estimate the single net resultant muscle force required to produce each measured external force. The external forces were estimated for the anterior abdominal muscle equivalent (A) during flexion, for the erector muscle equivalent (E) during extension, and for the equivalents producing the vertical components of the lateral abdominal-wall muscle forces during left- and right-lateral bending (V_L and V_R).

Statistical significance was tested by Student's *t* test. Intra-individual relative strength ratios were computed as described in the Results section, and means and standard deviations were calculated for various patient groups.

For a more complete description of the methods, as well as photographs of the apparatus used, see McNeill et al.[1]

RESULTS

Absolute Strengths

The male pain-clinic patients exerted mean forces during attempted trunk flexion, extension, and lateral bending that were on the order of 250 newtons, corresponding to mean moments at the L5–S1 level of 100 newton-meters. The corresponding mean strengths for the female patients were approximately 50% as great (Table 2). For the male patients, the estimated single equivalent muscle mean force resultants were approximately 1700 newtons in the erector muscles during attempted extension, 800 newtons in the anterior abdominal muscles during attempted flexion, and 600 newtons for the vertical component of the lateral abdominal muscles during attempted lateral bending. For the female patients, the mean values were approximately 800, 300, and 300 newtons, respectively, (see Table 2).

The ratios of the absolute strengths of the male pain-clinic patients to the absolute strengths of the healthy

Table 2. Mean Trunk Strength Forces and Moments About the L5 Level and Inter-Group Comparisons*

	Forces (newtons)				*Moments (newton-meters)*			
	Flexion	*Extension*	*Left-lateral bending*	*Right-lateral bending*	*Flexion*	*Extension*	*Left-lateral bending*	*Right-lateral bending*
Men								
Healthy subjects (27)	403	567	386	406	149	210	143	151
Patients (16)	288	245	218	249	110	95	84	96
Women								
Healthy subjects (30)	257	347	229	237	87	117	78	80
Patients (17)	135	129	107	127	46	45	37	44
Ratios								
Patients/healthy subjects								
Male	0.71	0.43	0.56	0.61	0.74	0.45	0.59	0.64
Female	0.53	0.37	0.47	0.54	0.53	0.38	0.47	0.55
Females/males								
Healthy subjects	0.64	0.61	0.53	0.58	0.5ε	0.56	0.55	0.53
Patients	0.47	0.53	0.49	0.51	0.42	0.47	0.44	0.46

* Data for healthy subjects obtained from McNeill et al.[1]

male subjects studied by McNeill[1] were approximately 45% during attempted extension, 60% during attempted lateral bending, and 70% during attempted flexion. For the women, the corresponding percentages were approximately 40, 50, and 50%, respectively.

When the absolute strengths for the patients at the pain clinic were compared with those for the patients studied by McNeill et al.[1] at the orthopaedic office practice, the office-practice patients were usually somewhat stronger, but in no case did the difference achieve statistical significance.

Intra-individual Relative Strength Ratios

The following values were calculated on an intra-individual basis: the ratio of extension force to flexion force and its corresponding muscle force resultant ratio (E to A); the ratio of left-lateral to right-lateral equivalent muscle force (V_L to V_R); and the ratios of both E and A to both V_L and V_R, respectively.

When the ratios for the patients from the pain clinic were compared with the ratios for the healthy subjects, they indicated that the patients limited their performance more during attempted extension than during flexion or lateral bending. Ratios of extension to flexion and of E to A were smaller for the patients than for the healthy subjects, and these differences were statistically significant at the $P < 0.001$ level. Ratios of E to V_L were also smaller for the patients, and the differences were significant at the $P < 0.01$ level. This was true for both men and women (Table 3). In addition, male patients exhibited higher ratios of A to V_L than did healthy men, with the differences significant at the $P < 0.01$ level. This was true for both men and women (Table 3). In addition, male patients exhibited higher ratios of A to V_L than did healthy men, with the differences significant at the $P < 0.05$ level. Female patients were weaker during left-lateral bending than during right-lateral bending, whereas healthy subjects had equal mean strengths for right-lateral and left-lateral bending, and the differences were significant at the $P < 0.002$ level.

When the intra-individual relative strength ratios of the patients from the pain clinic were compared with those of the patients from the office practice no statistically significant differences were found for the ratios of extension to flexion force, E to A, E to V_L, or A to V_L. Relative weakness during attempted extension was apparent for both patient groups. Both male and female patients from the office practice were slightly stronger during left-lateral than during right-lateral bending. This trend was reversed for the patients from the pain clinic, and these differences were statistically significant for both the men ($P < 0.01$) and the women ($P < 0.05$).

Table 3. Mean Estimated Single Equivalent Muscle Resultants (Newtons) Required to Produce Measured Strengths*

Type of muscle	*Healthy men*	*Male patients*	*Healthy women*	*Female patients*	*Ratios: patients/healthy subjects*	
					Men	*Women*
E in extension	4057	1722	2243	800	0.42	0.36
A in flexion	1153	798	635	323	0.69	0.51
V_L in left-lateral bending	953	550	498	238	0.58	0.48
V_R in right-lateral bending	1002	630	516	282	0.63	0.55

* Data for healthy subjects obtained from McNeill et al.[1]

Table 4. Means of Intra-Individual Strength Ratios

Intra-individual relative strength ratios	Healthy men	Male patients	Healthy women	Female patients	Significance of patient–healthy subject difference	
					Men	Women
Extention/flexion	1.37	0.92	1.41	0.95	$P < 0.001$	$P < 0.001$
E/A	3.42	2.31	3.53	2.37	$P < 0.001$	$P < 0.001$
Left-lateral/right-lateral bending	0.96	0.86	0.99	0.83		$P < 0.01$
E/V_L	4.25	3.29	4.46	3.31	$P < 0.01$	$P < 0.01$
A/V_L	1.22	1.52	1.30	1.53	$P < 0.05$	

* Data for healthy subjects obtained from McNeill et al.[1]

Effects of Sciatica

In terms of absolute strengths, the patients with sciatica (i.e, with any pain referred inferiorly from the low-back region) were generally stronger than those without sciatica (Table 5). However, only a few of the patients from the pain clinic did not have sciatica, and the differences between pain-clinic patients with and without sciatica failed to achieve statistical significance. There were no statistically significant differences in absolute strengths between those patients from the pain clinic and those of the patients from the office practice, regardless of whether or not they had sciatica.

In terms of intra-individual relative strength ratios, the differences between those patients from the pain clinic who had sciatica and those who did not were not generally statistically significant. Similarly, differences between the pain-clinic and the office-practice groups, when these were subdivided into groups of patients with and without sciatica, were not generally statistically significant. There were isolated exceptions to these statements, but they were scattered and did not seem to follow any clear patterns. More complete tabulations of the data are available from the authors.

Pain Severity Before and During Testing

Three male patients and one female patient reported experiencing somewhat severe (Grade 3) pain at the start of the tests; all other patients reported mild or moderate pain (Grades 1 or 2). There did not seem to be any associations between the grades of pain at the time of testing and any of the measures of patient performance.

During testing, 33% of the patients reported pain during attempted flexion, 42% during attempted left-lateral bending, 55% during attempted right-lateral bending, and 64% during attempted extension. Somewhat severe pain was reported by two patients during extension and by three during right-lateral bending. Otherwise, the reported pain was graded none, mild, or moderate. A patient who reported pain during a test did not tend to perform that test weakly.

Effect of Surgery

There did not seem to be any marked differences in performance, measured in terms of mean absolute trunk strengths or mean relative strength ratios, between the

Table 5. The Effects of Sciatica Symptoms on the Strengths of the Patients from the Pain Clinic

	Number of patients	Forces (newtons)				Intra-individual relative strength ratios				
		Flexion	Extension	Left-lateral bending	Right-lateral bending	Extension/flexion	E/A	Left-lateral/right-lateral bending	E/V_L	A/V_L
Men										
No sciatica	4	224	228	199	221	0.99	2.49	0.88	3.19	1.31
Any sciatica	11	305	244	219	253	0.89	2.23	0.86	3.30	1.59
Right sciatica	2	305	223	158	208	0.73	1.82	0.76	3.76	2.07
Left sciatica	6	375	293	288	323	0.84	2.11	0.89	3.10	1.49
Bilateral sciatica	3	166	160	122	145	1.11	2.77	0.86	3.41	1.47
Women										
No sciatica	3	155	90	70	87	0.58	1.45	0.85	3.39	2.35
Any sciatica	11	122	128	99	118	1.05	2.62	0.84	3.51	1.42
Right sciatica	3	103	103	68	78	1.02	2.55	0.89	4.27	1.67
Left sciatica	5	107	124	97	121	1.17	2.92	0.78	3.37	1.30
Bilateral sciatica	3	163	166	140	153	0.88	2.20	0.88	2.98	1.39

* Results for one man and for three women were not evaluated.

patients who had had back surgery and those who had not.

Load Release Times

During the experiments, patients from the pain clinic seemed to relax more slowly after their maximum efforts than did healthy subjects. A pilot check of the force recordings confirmed this finding. Ten randomly selected male patients over age 30 used a mean of 2.2 seconds to relax to one-half of the maximal exertions they had demonstrated during flexion, extension, and left-lateral bending. In contrast, ten randomly selected healthy men over age 30 used only 1.3 seconds.

DISCUSSION

Because a main purpose of this paper was to compare maximum voluntary trunk strengths of the patients from the pain clinic with those of the patients from the orthopaedic office practice, the question of the extent to which the two patient groups differed is important. The characteristics of the two types of patients were not mutually exclusive. Some of the patients from the office practice were more disabled by their symptoms than were some of the patients from the pain clinic. The differences between the groups were indicated only roughly by a comparison of the general pain grade assigned to the office-practice patients with the general disability grade assigned to the pain-clinic patients (see Table 1), since the grades were assigned on the basis of the patients' subjective responses to different questionnaires. Moreover, the pain grades assigned for both groups at the time of testing, which are fully comparable, indicate that the two groups had almost identical mean-pain values.

Nevertheless, we think that on the average there were real differences between the two patient groups and that the patients from the pain clinic were representative of chronically, significantly disabled low-back patients. The mere fact that they sought four weeks of intensive treatment as inpatients indicates this. Fourteen of the 33 patients had had back operations, and seven of these had had two to four operations. Of the 40 patients from the orthopaedic office practice, 11 had had back operations, but only three had had two operations, and none had had more than two operations. Almost two-thirds of the patients from the pain clinic had regularly taken narcotic medication for their symptoms.

Our findings indicate that in regard to maximum voluntary static trunk strengths in the standing position, the patients from both groups behaved in the same way. When compared on an intra-individual basis, their erector muscle strengths were smaller than their anterior and their lateral-abdominal muscle strengths. Comparison of strengths on an intra-individual basis substantially avoids the problems created by the effects of the patients' general relative weakness and questions of motivation. It is not likely that a subject would avoid exertion during trunk extension more than during other types of movement because of psychologic reasons. The intra-individual relative strength ratios seem to reflect organic sources of limitation of performance, and apparently, these sources are similar for both classes of patients. Both classes of patients showed intra-individual relative strength ratios that differed statistically from those of healthy subjects at the $P < 0.001$ level, while there were few statistically significant differences in relative strengths between the two patient groups.

It is sometimes claimed that patients with low-back disorders have weak abdominal muscles. On an absolute strength basis, this was true of our patients. But the claim implies that the abdominal muscles are weak relative to the other major muscles of the lower trunk, and here our findings are to the contrary. If abdominal muscle strength is evaluated by comparing it with muscle strengths during attempted extension or lateral bending, both patient groups had mean relative abdominal strengths that equalled or exceeded those of the healthy subjects. The mean relative abdominal strengths of both groups of male patients exceeded those of the healthy men, with the differences statistically significant at the 5% level.

The presence of sciatic symptoms clearly influenced the trunk strengths of the patients from the orthopaedic office practice; those with sciatica were weaker during attempted extension than were those without. This did not seem to be the case with the patients from the pain clinic; however, too few of them were free of sciatic symptoms for a definite determination to be made. Neither did a history of back surgery nor a report of pain arising during testing influence the performance of the patients from the pain clinic in consistent ways.

A discussion of some of the biomechanical implications of the finding that the patients' muscles were weak during attempted trunk extension in comparison with other types of exertions is given by McNeill et al.[1]

CONCLUSIONS

(1) The patients from the pain clinic had approximately 50% of the trunk strengths of the healthy patients.

(2) Relative to the strengths of their other muscles, the patients from the pain clinic did not have weak anterior abdominal muscles; relative strength of attempted flexion was greater for the male patients than for healthy men. However, such was not the case for absolute abdominal strengths.

(3) Relative to their other trunk strengths, the patients from the pain clinic were weak during attempted trunk extension.

(4) There were no significant differences in mean behavior between the patients from the pain clinic, who

apparently had major long-term disabilities, and the patients from the orthopaedic office practice, who were apparently less disabled.

(5) The findings based on intra-individual performance ratios imply that performance is limited by organic sources that are similar for the patients from the pain clinic and from the orthopaedic office practice, despite differences in the apparent degrees of disability between these two patient groups.

REFERENCE

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