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ISOKINETIC AND PSYCHOPHYSICAL LIFTING STRENGTH, STATIC BACK MUSCLE ENDURANCE, AND MAGNETIC RESONANCE IMAGING OF THE PARASPINAL MUSCLES AS PREDICTORS OF LOW BACK PAIN IN MEN

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ABSTRACT. Magnetic resonance imaging was used to determine the cross-sectional areas and the T2-weighted and proton density-weighted signal intensities of the paraspinal muscles in a group of 128 men, aged 35–63, who had varied histories of occupational and leisure-time physical activities. These measures, and the isokinetic lifting, psychophysical lifting, and static back muscle endurance tests were examined as predictors of low back pain over 12 months of follow-up, in the 43 men who reported no low back pain in the year preceding testing. None of the imaging measures or the muscle function tests was useful as a predictor of future low back pain. Associations with the frequency of low back pain before testing were investigated in the larger group. Smaller total cross-sectional area of the paraspinal muscles and greater signal intensities had weak but significant correlations with more frequent low back pain in the previous year, possibly due to muscle atrophy.

Key words: lifting, low back pain, magnetic resonance imaging, muscle-skeletal, muscular atrophy, prospective studies.

INTRODUCTION

Strengthening the trunk muscles is a common part of many preventive and therapeutic interventions, but most studies have found strength testing to be an ineffective predictor of future low back injuries or symptoms. After adjusting for age and sex, Battié et al. (2) found virtually no difference in torso lifting strength between those who later filed back injury claims and other blue-collar workers at an aircraft plant. In two separate studies of female nurses, isokinetic lifting strength failed to predict future back injury (14, 22) or pain (22). Isometric strength testing was also ineffective in another study of nurses (18). Similar results were found for isokinetic lifting strength and subsequent low back injury in a steel mill (6). Pre-employment testing for a wide variety of occupations found psychophysical lifting to be a poor predictor of future low back pain (20). Back muscle strength also had no association with the onset of sciatica in concrete reinforcement workers and house painters (19). Andersson (1) and Pope (17) reviewed earlier studies and concluded that strength testing must be job-specific to be a useful predictor of work-related injury.

In a study unrelated to occupation, an investigation was conducted on a group of women who had no clinical history of low back pain, had no work loss due to low back pain in the past year, and were never off work for more than one month because of low back pain (15). Here, too, isokinetic, isometric, and psychophysical lifting were not related to future low back trouble.

Unlike the lifting tests, static back muscle endurance has been shown to predict low back pain. Adjusting for age, sex and occupation (blue or white collar), it predicted first-time low back pain in a study of truck drivers, school cleaners, and office workers and cleaners (12). In a population-based study, the effect was found among men, but not women (4). Static back muscle endurance was not a significant determinant of the recurrence or persistence of low back pain.

The morphology of the paraspinal muscles can be examined using computed tomography (CT) and magnetic resonance (MR) imaging. Chronic back pain has been associated with lower CT scan image density (10), and post-operative low back pain patients had significantly lower image density than controls (13). There is also evidence showing that the cross-sectional area of the paraspinal muscles is smaller in those with chronic low back pain (10, 16). However, we are unaware of any studies that have assessed muscle morphology as a predictor of future low back pain.

In our study, we used magnetic resonance imaging to determine the cross-sectional areas and the T2-weighted and proton density-weighted signal intensities of the paraspinal muscles. The aim was to see if any of these measures, or the isokinetic lifting, psychophysical lifting, or static back muscle endurance tests could predict low back pain over 12 months of follow-up, in men with varied histories of occupational and leisure time physical activities. Since the use of trunk muscle imaging in the study of low back pain is relatively new, we looked for associations with pain in the preceding year, as well.

METHODS

The subjects included in this study were among men selected from the Finnish Twin Cohort based solely on discordance in occupational materials handling, sedentary work, exercise, vehicular vibration, or cigarette smoking (3). It was not possible to find enough female twins with suitable differences in their occupational or smoking histories to include women in the study.

In the initial interview, subjects were asked how often they had experienced low back pain or ache in the preceding 12 months, and whether they had ever had an episode of low back pain lasting more than one day. Subjects were excluded if they had any current pain, colds, untreated high blood pressure, prior myocardial infarctions or other physical conditions that might affect back testing.

Three different aspects of back muscle function were evaluated, isokinetic and psychophysical lifting, and static back endurance. The isokinetic lifting was done from a forward bent to a straight standing position, with straight arms and legs. The lifting speed was 0.5 m/sec.; maximum lifting strength and the total work per lift were calculated. The psychophysical lifting test was similar to the acceptable isometric lifting force at knee-level test, except that the initial lifting position was the same as the isokinetic test described above (7). Each man was asked to use the strength he thought he could comfortably maintain for 5 seconds, without straining, and the mean of three trials was computed. Static back muscle extensor endurance was evaluated by timing how long the subject was able to hold the upper part of his body horizontally, while lying prone with no support beyond the upper border of the iliac crest. The testing methods and their reliability have been described in detail elsewhere (11).

Back muscle morphology was analyzed with MR imaging. Transverse sections, with the inclination positioned after each intervertebral space, were obtained for the four lower lumbar discs using a 1.5 tesla Siemens Magnetom MR equipment (Siemens AG, Erlangen, Germany) with surface coil, using a sequence SE 2450/22-90. Slice thickness was 3 mm and gaps between the slices 0.3 mm. The matrix was 192 × 256 and FOV 260 mm. The images were stored on optical disk and analyzed later using a computer program written for this purpose. The perimeters of the left and right erector spinae (including the multifidus), quadratus lumborum, and psoas major muscles and a sample of the cerebrospinal fluid were traced with a mouse by one of the authors (LG) and analyzed digitally. The L3-L4 level was chosen because the muscle cross-sectional area was greatest at this level in 70% of 20 test cases evaluated. The signal intensities of the muscles on proton density and T2-weighted images were measured. Variation in the signal intensity of the machine over time was adjusted by dividing the mean signal intensity of a subject's left and right muscle by the mean signal intensity of his cerebrospinal fluid, a method that has been used previously for MR image analyses (3, 8, 21). Repeatability of the digital analyses was excellent. The muscle tracing was repeated for 18 subjects, and the intraclass correlation coefficients were all at least 0.96.

Table I. *Frequency of low back pain in the 12 months before the initial interview (n = 128)*

	Frequency	Per cent
None	43	34
Once a year	16	13
2–3 times a year	28	22
Several times a year	13	10
At least once a month	11	9
At least once a week	11	9
Daily	6	5

Digital analysis of the MR images was carried out for 130 of the men eligible for strength testing. Twelve months after their initial interviews, 128 of these men were reached by telephone and asked about their frequency of low back pain or ache in the follow-up period. The 128 men ranged from 35 to 63 years of age (mean 48 years). Eighty-five of these men reported low back pain of varying frequency in the 12 months preceding the initial interview (Table I). Of the 43 men who reported no back pain, 13 reported low back pain of varying frequencies during follow-up, with 5 experiencing low back pain at least once a month (Table II). The age distribution of the 43 men was very similar to that of the larger group.

Logistic regression was used to evaluate potential predictors of back pain during follow-up. Spearman correlation coefficients were used to measure the cross-sectional ordinal association with the frequency of recent low back pain.

RESULTS

In the group of 43 men who reported no low back pain in the 12 months preceding the initial interview, the cross-sectional areas and signal intensities of the paraspinal muscles and the isokinetic and psychophysical lifting and static back muscle endurance tests were all considered as predictors of future low back pain. None of the factors was a significant predictor of reported low back pain

Table II. *Frequency of low back pain in the 12-month follow-up period among the 43 men who reported no low back pain in the 12 months before the initial interview*

	Frequency	Per cent
None	30	70
Once a year	5	12
2–3 times a year	3	7
Several times a year	0	0
At least once a month	1	2
At least once a week	1	2
Daily	3	7

Table III. *Means and standard deviations for MRI measures and muscle function tests for those with low back pain (LBP) during follow-up, and those with no pain, among men who reported no low back pain in the 12 months before the initial interview. P-values are from logistic regression*

	LBP ($n=13$)		No LBP ($n=30$)		
	Mean	SD	Mean	SD	p-value
Cross-sectional areas (mm²):					
Erector spinae	4904	747	4903	606	0.99
Quadratus lumborum	1431	374	1344	300	0.42
Psoas major	3019	667	2858	703	0.48
Total paraspinal	9355	1458	9106	1329	0.58
Proton density-weighted signal intensity (adjusted):					
Erector spinae	1.43	0.21	1.39	0.17	0.58
Quadratus lumborum	0.79	0.12	0.78	0.12	0.70
Psoas major	0.59	0.07	0.59	0.08	0.83
T2-weighted signal intensity (adjusted):					
Erector spinae	0.33	0.16	0.27	0.05	0.21
Quadratus lumborum	0.20	0.08	0.17	0.03	0.22
Psoas major	0.16	0.06	0.14	0.02	0.21
Maximum isokinetic force (N)	1034	325	1029	224	0.95
Psychophysical lifting strength (N)	410	168	357	160	0.33
Static back endurance time (seconds)	80	46	84	45	0.83

during the 12-month follow-up (Table III). The paraspinal muscles of those with back pain were slightly larger. Most of the signal intensities were slightly higher, perhaps due to greater amounts of fat and connective tissue. The men who reported back pain used slightly greater force on the two lifting tests, and had slightly shorter static back muscle endurance times. But all these differences are very small and none approached statistical significance. In addition, we examined whether any of these factors would predict low back pain occurring at least once a month during follow-up. Only 5 men reported low back pain of that frequency, so the power is limited, but the results were similar. We also assessed age, weight, and height as possible confounders, but the differences were still not significant.

Table IV. *Spearman correlation coefficients for the ordinal association of MRI measures and muscle function tests with the frequency of low back pain in the previous 12 months ($n=128$)*

	Correlation coefficient	p-value
Cross-sectional areas (mm²):		
Erector spinae	−0.12	0.162
Quadratus lumborum	−0.17	0.053
Psoas major	−0.13	0.133
Total paraspinal	−0.18	0.044
Proton density-weighted signal intensity (adjusted):		
Erector spinae	0.19	0.031
Quadratus lumborum	0.21	0.018
Psoas major	0.31	< 0.001
T2-weighted signal intensity (adjusted):		
Erector spinae	0.20	0.024
Quadratus lumborum	0.19	0.029
Psoas major	0.19	0.028
Maximum isokinetic force (N)	−0.08	0.389
Psychophysical lifting strength (N)	−0.01	0.889
Static back endurance (seconds)	0.03	0.703

A smaller total cross-sectional area of the paraspinal muscles was significantly associated with more frequent low back pain in the previous year, as were greater signal intensities of the muscles (Table IV). None of the correlations was very strong; the greatest, for the proton density-weighted signal intensity of the psoas major, was 0.31. Among those experiencing pain at least once a month, the cross-sectional areas of the erector spinae muscles were significantly smaller (4559 vs 4939 mm², $p=0.03$), as were the total cross-sectional areas of the paraspinal muscles (8469 vs 9144 mm², $p=0.03$). There were no significant associations of the frequency of low back pain in the preceding year with either of the lifting tests or the static back muscle endurance test (Table IV).

DISCUSSION

For those with no low back pain in the previous year, neither the three commonly-used tests of back muscle function, nor the MR image measures were significant predictors of low back pain. The lack of association between the static back muscle endurance time and future low back pain was in contrast to the findings of two previous studies (4, 12). In the study by Luoto et al. (12), the subjects had their arms by their sides, rather than behind their heads. The men in Biering-Sørensen's study (4) held their arms across their chest. It seems unlikely, however, that the difference in arm placement would explain our negative findings. The reported incidence of low back pain was similar in all three studies, but perhaps the study populations differed in some other important way. The men in Biering-Sørensen's study had static back muscle endurance times roughly twice as long as Luoto's or ours, which indicates either a difference in the condition of the subjects or in how the test was conducted. It is also possible that the significance of the results of Luoto and Biering-Sørensen or the lack of significance of ours is due to chance (type I or type II statistical error).

Our finding that the isokinetic and psychophysical lifting tests were not significantly related to future low back pain was similar to what Newton et al. (15) found among a group of women. Earlier studies examining these tests had not been restricted to subjects with no recent low back pain, though several studies excluded workers with current low back pain, among other criteria (2, 14, 19). Even so, similar strength tests were found to be ineffective predictors of back pain and injury.

One reason that strength test results may not predict future back trouble is that people who lack strength in their back muscles may avoid activities that might put them at risk of injury. To the degree that muscle size reflects strength, avoidance of risky activity may also be a factor in the lack of a significant relationship between the cross-sectional areas and future pain. Or it could be that unless small muscle size resulted from atrophy due to past pain, size itself is not so important in the prevention of future pain. We found no significant evidence that either larger or smaller muscle cross-sectional areas are a risk indicator for future back pain.

We also found no significant relationship between the T2- and proton density-weighted signal intensities and future low back pain. The signal intensities from the MR image sequences we used mostly reflect the water content of the muscle. Fat will have higher signal intensity, but these particular MR image sequences may not be sensitive enough to the differences in the levels of fat that occur in men with no low back pain. Other sequences may provide better measures.

Though none of the MR image measures was a significant predictor of future low back pain, we did find an association between more frequent low back pain in the preceding 12 months and smaller total cross-sectional area of the paraspinal muscles. In two previous studies of subjects with chronic low back pain, smaller cross-sectional areas of the erector spinae muscles were found, compared with healthy controls, suggesting muscle atrophy (10, 16). Our subjects had a range of low back pain symptoms, and probably few were as disabled as those with chronic pain in the other studies, so smaller differences could be expected. Moreover, muscle disuse does not always result in muscles with smaller cross-sectional areas. Sometimes when muscle fibers decrease from inactivity, fat is deposited in place of the muscles and the dimensions of the muscle do not change much. Still, the subjects who reported having pain at least once a month had significantly smaller cross-sectional areas of the erector spinae muscles than the others. Higher signal intensities of the muscles, were also associated with more frequent low back pain. If the association is due to a greater amount of fat in the muscle, then it is consistent with two earlier findings from CT scans (10, 13).

We considered only self-reported frequency of low back pain. Problems with the accuracy of low back pain classification based on interviews have been previously described (5, 9), and we also noted some inconsistencies. For example, two people who reported daily low back pain in the previous 12 months said later in the interview that they had experienced no episodes of low back pain lasting longer than a day. However these inconsistencies did not appear to account for our negative findings. Because of the number of predictors and outcomes, there was a potential for the problem of multiple comparisons. The findings for MR imaging and recent pain were consistent, and so probably represent real associations. Since none of the prospective relationships was statistically significant, ''chance'' findings did not turn out to be an issue there.

The muscle function tests and MR image measures we investigated could still have prospective value for other pain outcomes, or for specific clinical diagnoses. They may turn out to have some minor role if other factors contributing to back pain can be better quantified and controlled for. But the fact that there have been so few prospective findings related to trunk muscle function makes it unlikely that major associations would be found, even with other study designs.

The isokinetic lifting, psychophysical lifting, and static back muscle endurance testing and the MR image measures are all attempts to assess the capabilities of the back. These assessments may be useful in clinical or rehabilitation settings, but they are questionable as predictors of future low back pain.

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