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A SUBMAXIMAL BACK EXTENSION ENDURANCE TEST UTILISING SUBJECTIVE PERCEPTION OF LOW BACK FATIGUE

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ABSTRACT. The present study was designed to evaluate the diagnostic value of a new submaximal back extension endurance test in the classification between patients with non-specific chronic/recurrent low back trouble (LBT) and controls. The back pain questionnaires included pain duration, intensity, regularity and the Pain & Disability Index. The subjects performed dynamic back extensions on a specially designed measurement and training unit at a fixed repetition rate with a load that was based on the subject's estimated upper body mass. The degree of perceived fatigue (unmodified Borg scale, 6–20) was inquired in 15 second intervals throughout the protocol and the slope (change/minute) was calculated. The Borg scale slope increased faster and the score at the end of the test was higher in the LBT group than in the control group during the test. Receiver operating characteristics analysis revealed significant diagnostic value for the Borg scale slope (0.74) and for the Borg scale at the end of the test (0.70). We conclude that LBT patients experience fatigue faster than controls during a repetitive submaximal back extension task. The test may offer a low-risk, low-cost evaluation method for assessing the severity of LBT when combined with other relevant clinical data.

Key words: deconditioning; endurance; low back pain; low back trouble; physical measures.

INTRODUCTION

Many low back pain (LBP) patients develop a "deconditioning syndrome" (22) due to fear of pain and avoidance behaviour (19). Behavioural avoidance can cause different problems. A decrease in physical activity can result in reduced lumbar mobility and loss of muscle strength and endurance because of muscle atrophy (1, 6, 8, 12, 18), i.e. physical deconditioning. As a part of the deconditioning syndrome, reduced endurance capacity of paraspinal muscles has been related to chronic LBP (4, 15, 26). However, only few objective methods and tests to measure this phenomenon exist so far. In recent years electromyographic (EMG) spectral indices and their shift toward lower frequencies during physical loading have been promising in objectively monitoring paraspinal muscle fatigue (7, 20, 24, 25, 28).

Most endurance test protocols are based on techniques where the test is performed up to maximal exertion with a certain percentage of maximal voluntary contraction (MVC) in a static condition. This type of test protocol has, however, major flaws (14). Maximal voluntary contraction may not be a true MVC since pain, fear of pain and motivation are factors influencing the results; the same factors are affecting the time of exertion. The MVC testing also imposes possible risks of injury. Moreover, sustained static fatiguing contractions of back muscles with high level of loading are seldom used in everyday life situations, but the daily movements are mostly dynamic (isoinertial) and loads are light (23).

Dynamic protocols have been less frequently used in the testing of back muscle function due to, for example, problems concerning the reliability of the test results. In our previous study, we developed a submaximal dynamic back extension endurance test with acceptable reliability (17). The loading in the test was based on upper body weight instead of MVC. In the test, the correlations between objective EMG spectrum parameters of back extensor muscle fatigue and a subjective experience of back muscle fatigue using an unmodified Borg scale (5) were high at the presacral level (coefficients >0.84). This lead to an idea to study whether the test would provide sufficient validity for testing low back endurance without any electronic devices. The aim of the present study was

Table I. *Subject characteristics:* n *(patients) = 20 (10 M; 10 F);* n *(controls) = 20 (10 M; 10 F); means and standard deviations*

Variable	Patient						Control						Group effect	
	Both		Female		Male		Both		Female		Male		F	p
Age (yr)	40.1	8.7	38.8	9.9	41.5	7.6	40.5	8.7	38.1	8.0	42.9	9.1	0.0	0.8992
Height (cm)	173.7	10.5	166.5	6.5	180.8	8.7	170.4	9.2	162.4	4.8	178.3	4.1	1.1	0.2973
Weight (kg)	76.1	16.9	68.3	16.5	83.9	13.9	70.2	14.4	57.7	6.4	82.7	7.1	1.4	0.2417
Habitual physical activity (MET h/wk)	12.5	11.0	11.3	6.6	13.8	14.5	14.6	12.6	16.7	16.1	12.6	8.3	0.3	0.5815
Pain and Disability Index (sum score)	14.0	12.1	20.2	13.4	7.7	6.6	1.3	2.8	0.9	1.9	1.8	3.5	20.6	0.0001
LBP now (10 cm VAS)	2.3	2.1	2.7	2.0	1.9	2.3	0.5	0.7	0.5	0.7	0.5	0.8	13.8	0.0007
LBP during latest six weeks (10 cm VAS)	4.9	3.2	5.8	3.0	4.1	3.4	0.5	0.7	0.6	0.7	0.4	0.7	35.0	0.0000
LBP frequency (10 cm VAS)	3.8	3.1	4.3	3.2	4.3	3.2	1.1	1.8	1.5	2.3	0.8	1.0	11.5	0.0016

to evaluate the diagnostic value of a submaximal repetitive back extension endurance test using the Borg scale for assessment of perceived fatigue in the classification between chronic LBP patients and controls, and to analyse associations between the fatigue parameters and self-experienced pain and disability characteristics, and habitual physical activity.

SUBJECTS AND METHODS

Subjects

Twenty low back pain patients (10 males and 10 females) and 20 age- and sex-matched controls (10 males and 10 females) were tested in a cross-sectional fashion. The patients were suffering from non-specific chronic/recurrent low back trouble (LBT) (duration less than three months; on the average 6.7 years, SD 4.8 years) participating in an outpatient active functional restoration programme without indications for surgical treatment. The patients were tested at the beginning of the treatment programme. The voluntary controls had no previous severe low back problems. No significant differences were found between the groups in age, height, weight or habitual physical activity. The subject characteristics are presented in Table I.

Measurements

Endurance test. The patients and controls were tested in a specially designed back extension training unit (DBC110, DBC International Ltd, Vantaa, Finland) (Fig. 1).

In the device, a fixation mechanism for hips, knees and feet was adjusted in such a way that the vertebral columns below L3 level were guided not to move. A cam mechanism created a variable resistance pattern (isoinertial movement). The movement range was adjusted between 25° flexion and 5° extension and the load level was calculated on the basis of upper body mass (UBM), sex and age. The UBM was calculated according to the formula: UBM (kg) = [body weight (kg) × 0.6 × height (m) × 0.4]. Sex and age factors were based on normative data. Finally load = UBM × (sex and age factor) × Z, where Z denotes an experimental factor that was adjusted to achieve maximal fatigue between two and four minutes among controls.

In the submaximal test, the subjects performed 45 dynamic upper trunk extensions in 90 seconds, and the rate

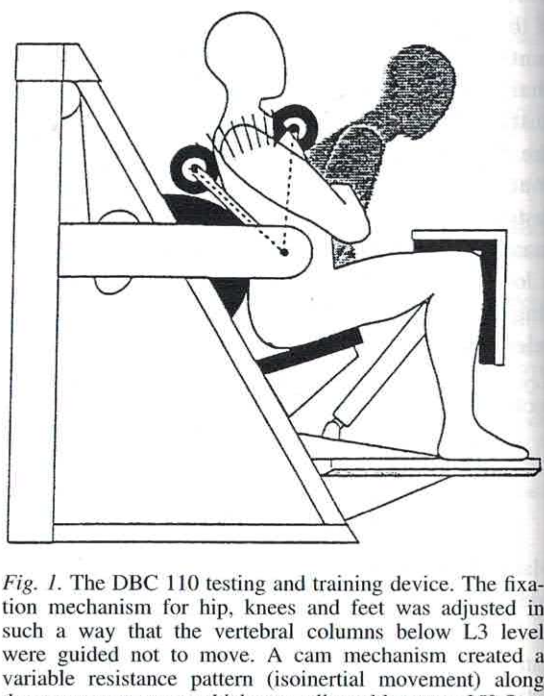

Fig. 1. The DBC 110 testing and training device. The fixation mechanism for hip, knees and feet was adjusted in such a way that the vertebral columns below L3 level were guided not to move. A cam mechanism created a variable resistance pattern (isoinertial movement) along the movement range which was adjusted between 25° flexion and 5° extension.

Table II. *The unmodified Borg scale. The perceived rating was inquired with 15 second intervals and the slope was calculated*

Rating of perceived exertion	
	6
Very, very light	7
	8
Very light	9
	10
Fairly light	11
	12
Somewhat hard	13
	14
Hard	15
	16
Very hard	17
	18
Very, very hard	19
	20

was controlled by a metronome giving audio-visual signals. The subjects were instructed to hold the muscular tension at both ends of the movement range. Exercise tasks were performed up to 90 seconds, or if the subject was unable to do so, until exhaustion. Exclusion criteria was set to the point where the subject could no longer keep up with the required repetition rate or stopped because of maximal fatigue.

Assessment of fatigue. A degree of perceived fatigue was inquired after the first three repetitions (beginning), in 15 second intervals, and at the end of the exercise task by using the unmodified Borg scale (5) (Table II), where scale ranged between 6 and 20.

Borg scale ratings were analysed in the beginning and at the end of the exercise task, and a slope (change units/minute) was calculated. In case the subject stopped because of maximal fatigue, the total time until exhaustion was recorded.

LBP questionnaire. The questionnaire included, in addition to sociodemographic variables, the duration in years of LBP, its regularity (100 mm VAS scale) and intensity (100 mm VAS scales for present pain and pain during the preceding six weeks). Habitual physical activity was assessed as frequency, intensity and duration, and a product of them (MET hours/week) score was calculated (2, 29). The subjects also answered a questionnaire concerning pain and disability due to the back disorder (Pain and Disability Index, PDI) (10, 11).

Statistical analysis. Statistical analyses included descriptive statistics (means and distributions), analyses of variance (ANOVA), Pearson product–moment correlation, and multiple regression analyses. These analyses were calculated by using the Statistica for Windows 4.5® software. Receiver operating characteristics (ROC) analysis was used to calculate the discriminatory power of the Borg scale scores and Borg scale slope. The areas under ROC curves and standard errors were calculated on the basis of earlier reports (3, 9, 13). In the categorisation of patients and controls, sensitivity, specificity, and predictive values for the Borg scale ratings with specified cutpoints were calculated. These analyses were done with the GraphROC 1.5® software.

RESULTS

Low back fatigue

No difference in the perceived exertion was found at the beginning, i.e. first seconds, of the test between the groups. During the 90 second dynamic endurance test, the patients experienced low back fatigue significantly faster than the controls on average (higher Borg scale slope, $p = 0.02$) (Fig. 2). Also, the level of experienced fatigue (Borg scale rating) was higher at the end of the test among patients than controls on average ($p = 0.003$). Five of the 20 patients were not able to perform the 90 second test period, while all the 20 controls were able to perform until the end of the 90 second submaximal test period (Fig. 2).

Diagnostic value and categorisation

The ROC curves were calculated for Borg scale slope and Borg scale at the end of the test. Areas under the ROC curves were 0.74 (s.e. 0.08) and 0.70 (s.e. 0.09), respectively. These results indicate that this test does have statistically significant diagnostic value in the categorisation of the chronic LBP patients and controls.

We calculated the cutpoints for classification of the LBP and control groups based on values for sensitivity, specificity and predictive value. An endurance performance characteristic for LBP patient was slope higher than or equal to 5.1 units/minute (sensitivity 0.55; specificity 0.95; positive predictive value 0.92), and a Borg scale value at the end of the test higher than or equal to 18 (sensitivity 0.47; specificity 0.80, positive predictive value 0.64). Correspondingly, an endurance performance characteristic for a healthy control was a slope smaller than or equal to 3.8 units/minute (sensitivity 0.90; specificity 0.60; negative predictive value 0.86), and a Borg scale value at the end of the test smaller than or equal to 15 (sensitivity 0.80; specificity 0.45; negative predictive value 0.75).

Using the above-mentioned cutpoint levels 5.1 for the slope or 18 for the Borg scale at the end of the exercise task, 16 patients (7 females, 9 males) were categorised properly (as patients) out of the 20 (80%). Correspondingly, using the above-mentioned cutpoint levels 3.8 for the slope or 15 for the Borg scale at the

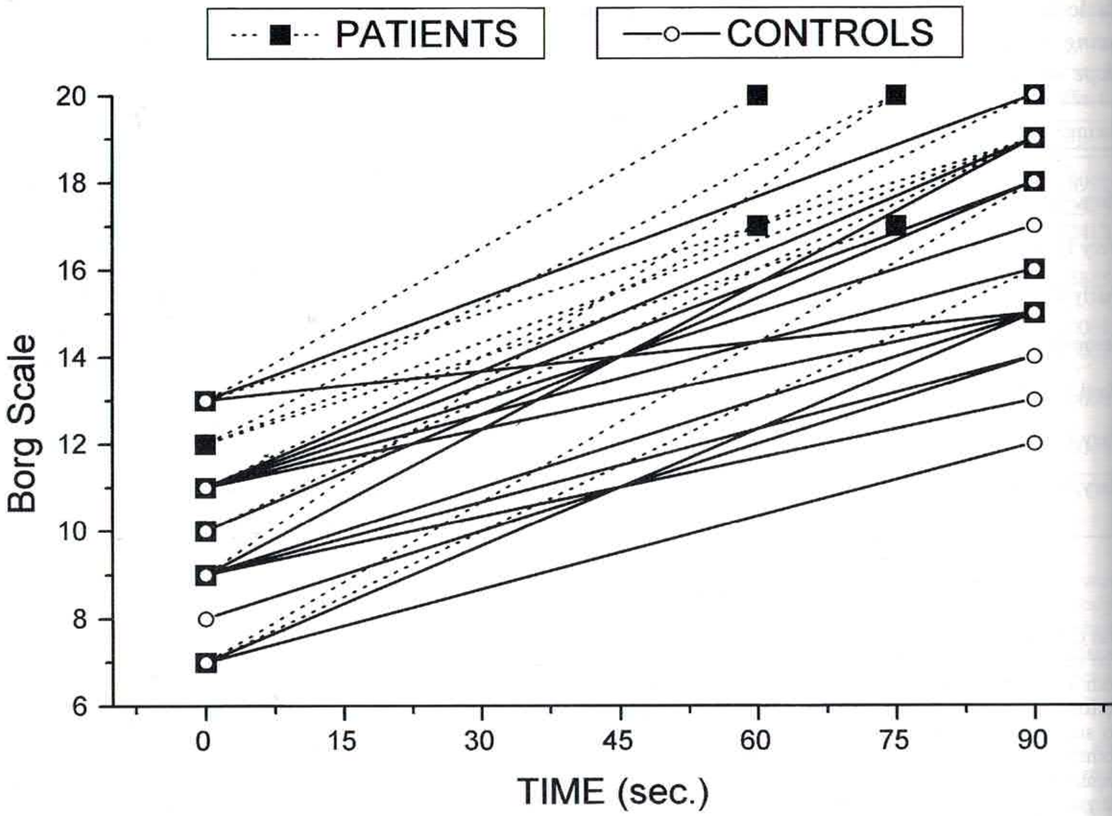

Fig. 2. The increase in perceived fatigue during the repetitive submaximal 90 second back extension test. The difference between patients and controls was statistically significant both for the scale slope ($p = 0.02$) and the scale value at the end of the test ($p = 0.003$).

end of the exercise task, 12 controls (5 females, 7 males) were categorised properly (as controls) out of the 20 (60%). Altogether, 28 of the 40 subjects (70%) were categorised correctly with the above-mentioned cutpoint levels.

Correlations between LBP characteristics and fatigue

Low to moderate ($r < 0.38$) correlations were found between the endurance parameters and self-experienced impairment (PDI) ($r < 0.34$), LBP pain intensity VAS either now ($r < 0.33$) or at six weeks ($r < 0.32$), LBP frequency VAS ($r < 0.38$) and physical activity ($r < -0.23$). In multiple regression ($F_{7,32} = 2.4$, $p = 0.039$; $R^2 = 0.35$), the only variables with significant association to Borg scale slope were grouping between chronic LBP patients and controls ($p = 0.015$) and LBP during the latest six weeks ($p = 0.028$), but not the present pain intensity level. None of these variables were associated with the Borg scale at the end of the exercise task in multiple regression.

DISCUSSION

The results of the present study showed that these chronic LBT patients experienced low back fatigue faster in a standardised dynamic back extension exercise task than healthy controls on average. The results were not affected by present back pain, but the only statistically significant determinants of perceived fatigue in multiple regression were pain chronicity and pain during the latest six weeks. It seems that the reduced endurance is a result of long-term deconditioning due to fear of pain and reduced physical activity rather than the present pain. However, care must be taken in this interpretation due to the rather small number of subjects.

It was possible to define cutpoint levels with predictive values to categorise the subjects correctly either to chronic LBP patients or to controls. The categorisation was correct in 70% of cases. However, the predictive value in the categorisation was better in the classification of test results related to disease than those related to health. Predictive values for health/disease classification have not been described earlier in back endurance test protocols. The diagnostic value of subjective assessment of fatigue by the Borg scale is acceptable in a statistical sense, but diagnostic procedures concerning the existence or severity of LBT based on endurance measurements alone are not justified since both false positive and false negative rates are unacceptably high. Perhaps the test may offer a low-risk, low-cost evaluation method for assessing the severity of LBT when combined with other relevant clinical data on LBT.

The low back pain patients had been suffering from non-defined chronic/recurrent LBP for an average of 6.7 years. They are representative of non-specific chronic LBT outpatients who are still able to work, with occasional absenteeism. The diagnostic value of the test protocol in the classification of specific disorders or more severe disabling back pain still remains unknown.

The validity of a test, i.e. the fundamental discriminatory power of any test to classify samples into alternative groups, can be summarised by the area under the ROC curve (3, 13). The numeric value refers to the probability, for example, in which a randomly selected patient has to obtain a higher (different) value in the test than a randomly selected healthy person. The area under the ROC curve for an ideal test is 1.0; for a test of no value the area is 0.5 or less. Areas higher than 0.7 usually refer to statistically significant discriminatory power and an area higher than 0.8 indicates good discriminatory power (9). However, a selection based solely on the area value is not appropriate. If, for example, two curves differ markedly in their overall slopes, they still may intersect at some decision point. Therefore, a test performance has to be translated into optimal diagnostic efficacy by selecting the operative point of maximal clinical yield. The selection of the cut-off value depends on the task, and there is not just one suitable method for calculating the optimal cut-off limits. This has been the basis for us to select the above-mentioned cutpoint levels.

The present dynamic test protocol appeared to be easy to apply, and it does not require expensive electronic devices or invasive methods. The load level is based on estimated upper body mass, which ensures the safety of the patient since no MVC measurements are required. Moreover, the test protocol is submaximal and therefore is not affected as badly by the subject motivation or fear of pain as are maximal test protocols. Many tests require measurements of MVC and are performed until fatigue (24, 25, 28), procedures which have flaws since MVC and endurance time are affected strongly by subject motivation. When patients are studied, pain is also a limiting factor and it imposes possible risks of injury. Therefore, this type of procedure is an ethical consideration (14).

Biering-Sörensen test has been frequently used to assess back extensor fatigability (4), which has also been associated with EMG studies measuring back muscle fatigability (20, 21, 27). None of these studies show attempts to measure the EMG spectral shifts from other sites than back muscles. Our preliminary EMG data (16) suggest that gluteal muscles are involved during static back endurance tests and therefore back muscle fatigability may not be the only factor limiting endurance performance. In our dynamic test protocol muscle activity is mainly originating from the lumbar area and gluteal muscles seem far less active. In that sense the test protocol used in this study is measuring more specifically back extensor fatigability, which seems to be impaired in chronic LBT. Our earlier studies have shown high correlations between subjective scoring of experienced fatigue and objective measures of fatigue using EMG spectrum parameters over the back extensors. The parameters measured have also appeared to be reliable (17).

In conclusion, it seems that chronic LBP patients suffer from increased back muscle fatigability. This is probably because of pain and illness behaviour which have lead to deconditioning of the back muscles. This increased fatigability in chronic non-specific back pain seems to be detectable with our dynamic submaximal back extension endurance test protocol. It was possible to define cutpoint levels with high predictive values to categorise the subjects correctly to chronic LBP patients. However, the predictive value in the categorisation was acceptable only in the classification of the test result as related to disease rather than to health.

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REFERENCES

1. Airaksinen, O., Hemo, A., Kaukanen, E., Saari, T., Sihvonen, T. & Suomalainen, O.: Density of lumbar muscles four years after decompressive spinal surgery. Eur Spine J *5:* 193–197, 1996.
2. American College of Sports Medicine Position Stand: The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. Med Sci Sports Exerc *22:* 265–274, 1990.
3. Beck, J. R. & Shultz, E. K.: The use of relative operating characteristic (ROC) curves in test performance evaluation. Arch Pathol Lab Med *110:* 13–20, 1986.
4. Biering-Sörensen, F.: Physical measurements as risk indicators for low back trouble over one-year period. Spine *9:* 106–119, 1984.
5. Borg, G.: Perceived exertion: a note on history and methods. Med Sci Sports *5:* 90–93, 1973.
6. Cooper, R. G., St Clair Forbes, W. & Jayson, M. I. V.: Radiographic demonstration of paraspinal muscle wasting in patients with chronic low back pain. Br J Rheumatol *31:* 389–394, 1992.
7. Dolan, P., Mannion, A. F. & Adams, M. A.: Fatigue of the erector spinae muscles. A quantitative assessment using "frequency banding" of the surface electromyography signal. Spine *20:* 149–159, 1995.
8. Fidler, M. W., Jowett, R. L. & Troup, J. D. G.: Myosin ATPase activity in multifidus muscle from cases of lumbar spinal derangement. J Bone Joint Surg *57B:* 220–227, 1975.
9. Forsström, J.: Machine learning in clinical medicine by knowledge acquisition from patient databases. MD thesis. Departments of Medicine and Clinical Chemistry, University of Turku, Turku, Finland, 1992.
10. Grönblad, M., Hupli, M., Wennerstrand, P., Järvinen, E., Lukinmaa, A., Kouri, J. P. & Karaharju, E. O.: Intercorrelation and test–retest reliability of the Pain Disability Index (PDI) and the Oswestry Disability Questionnaire (ODQ) and their correlation with pain intensity in low back pain patients. Clin J Pain *9:* 189–195, 1993.
11. Grönblad, M., Järvinen, E., Hurri, H., Hupli, M. & Karaharju, E. O.: Relationship of the Pain Disability Index (PDI) and the Oswestry Disability Questionnaire (ODQ) with three dynamic physical tests in a group of patients with chronic low-back and leg pain. Clin J Pain *10:* 197–203, 1994.
12. Hadar, H., Gadoth, N. & Heifetz, M.: Fatty replacement of lower paraspinal muscles: normal and neuromuscular disorders. Am J Roentgenol *141:* 895–898, 1983.
13. Hanley, J. A. & McNeil, B. J.: The meaning and use of the area under a receiver operating characteristic (ROC) curve. Radiol *143:* 29–36, 1982.
14. Hansson, T. H., Bigos, S. J., Wortley, M. K. & Spengler, D. M.: The load on the lumbar spine during isometric strength testing. Spine *9:* 720–724, 1984.
15. Hultman, G., Nordin, M., Saraste, H. & Ohlsen, H.: Body composition, endurance, strength, cross-sectional area and density of Mm erector spinae in men with and without low back pain. J Spine Disord *6:* 114–123, 1993.
16. Kankaanpää, M., Taimela, S., Airaksinen, O. V. & Hänninen, O. O.: Increased gluteal muscle fatigability of the low back pain patients during static back endurance test at seated posture. Med Sci Sports Exerc *28:* S48, 1996.
17. Kankaanpää, M., Taimela, S., Webber, C., Airaksinen, O. V. & Hänninen, O. O.: Lumbar paraspinal muscle fatigability in repetitive isoinertial loading: EMG spectral indices, Borg scale and endurance time. Eur J Appl Physiol, in press.
18. Laasonen, E. M.: Atrophy of sacrospinal muscle groups in patients with chronic, diffusely radiating lumbar back pain. Neuroradiol *26:* 9–13, 1984.
19. Letham, J., Slade, P. D., Troup, J. D. G. & Bentley, G.: Outline of a fear-avoidance model of exaggerated pain perception. Part 1. Behav Res Ther *21:* 401–408, 1983.
20. Mannion, A. F. & Dolan, P.: Electromyographic median frequency changes during isometric contraction of the back extensors to fatigue. Spine *19:* 1223–1229, 1994.
21. Mayer, T. G., Kondraske, G., Mooney, V., Carmichael, T. W. & Butsch, R.: Lumbar myoelectric spectral analysis for endurance assessment. A comparison of normals with deconditioned patients. Spine *14:* 986–991, 1989.
22. Mayer, T. G., Smith, S. S., Keeley, J. & Mooney, V.: Quantification of lumbar function. Part 2: Sagittal plane strength in low back pain patients. Spine *10:* 765–772, 1985.
23. Parnianpour, M., Nordin, M., Kahanovitz, N. & Frankel, V.: The triaxial coupling of torque generation of trunk muscles during isometric exertions and the effect of fatiguing isoinertial movements on the motor output and movement pattern. Spine *13:* 982–992, 1988.
24. Roy, S. H., De-Luca, C. J. & Casavant, D. A.: Lumbar muscle fatigue and chronic low back pain. Spine *14:* 992–1001, 1989.
25. Roy, S. H., De-Luca, C. J., Emley, M. & Buijs, R. J.: Spectral electromyographic assessment of back muscles in patients with low back pain undergoing rehabilitation. Spine *20:* 38–48, 1995.
26. Suzuki, N. & Endo, S.: A quantitative study of trunk muscle strength and fatigability in the low back pain syndrome. Spine *8:* 69–74, 1983.
27. Tsuboi, T., Satou, T., Egawa, K., Izumi, Y. & Miyazaki, M.: Spectral analysis of electromyogram in lumbar muscles: fatigue induced endurance contraction. Eur J Appl Physiol *69:* 361–366, 1994.
28. Van Dieen, J. H., Oude Vrielink, H. H. E., Housheer, A. F., Lätters, F. B. J. & Toussaint, H. M.: Trunk extensor endurance and its relationship to electromyogram parameters. Eur J Appl Physiol *66:* 388–396, 1993.
29. Wilson, P. W. F., Paffenbarger, R. S., Morris, J. N. & Havlik, R. J.: Assessment methods for physical activity and physical fitness in population studies: report of a NHLBI workshop. Am Heart J *111:* 1177–1192, 1986.

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