Chronic Low Back Pain Assessment Using Surface Electromyography

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This investigation examined surface electromyography as an additional tool in the comprehensive clinical evaluation of patients with chronic low back pain (CLBP). Electromyographic signals from electrodes placed in the lumbar area of 30 CLBP patients and 30 non-pain control subjects were compared. Patients and controls were matched for age, gender, and body mass index. Paired t *test showed a statistically significant difference between the two groups. The muscle activity mean values were threefold higher in CLBP patients than in controls* ($P < 0.00001$) *in the static testing, and twofold higher in CLBP patients than in controls* ($P < 0.00001$) *in the dynamic testing. Our findings indicate that surface electromyography assessment of the paraspinal muscle activity may be a useful objective diagnostic tool in the comprehensive evaluation of CLBP.*

Chronic low back pain (CLBP) is a major health problem with significant impact on the working population. In the United States, back pain ranks second only to upper respiratory infections as a reason for visits to physicians and is the leading reason for visits to orthopedic surgeons and neurosurgeons.[1,2] Annual medical costs for low back pain (LBP) are estimated to be as high as $24 billion. If disability and loss of work are included, estimates of the total annual cost of LBP approximates $50 billion.[3–5]

The Social Security Administration, one of the largest disability insurance programs in the United States, has noted difficulties with medical assessment of impairment and disability and has recognized great variability in physicians' impairment ratings by medical examiners.[6] A major problem in disability cases has been to provide objective substantiation that chronic pain, a subjective complaint, is really present. It has been pointed out that impairment ratings would be more meaningful if they were based on objective measurements rather than on subjective impression.[7]

Unfortunately, pain is a complex, subjective experience that is mediated through multiple components of the peripheral and central nervous system. Pain is a sensation conducted by A-delta and C nerve fibers to the brain. The A-delta fibers carry pain and temperature functions. The unmyelinated C fibers transmit nociceptive impulses. It is worth noting that some A-delta fibers may be polymodal responders, which will

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fire after a high threshold has been reached and actual tissue damage has occurred. These fibers have the property of lowering their active thresholds once they have been exposed to other nociceptive impulses. In the sensitized state, innocuous mechanical stimuli that previously did not evoke response produce nociceptive impulses, which continue after cessation of the stimulus. Sensitization to decreasing stimuli plays a role in the prolongation of acute pain and the development of chronic pain. The central nervous system becomes habituated to the sensory input to the point at which pain is perceived, even in the absence of a detectable lesion.[8]

The challenge of the clinician is to interpret the patient's description of his or her pain into anatomic and physiological correlates that will identify the injured structure. In the normal spine, the anterior vertebral bodies and their interconnecting disks provide weight-bearing and shock absorption. The spinal cord and nerve roots are protected by the posterior elements, including the vertebral arches, transverse spinal processes, and facet joints. The facets, ligaments, and paraspinal muscle provide stability and balance. Pain may arise from nearly any of these structures, but the precise source is often not identifiable.

Range of motion (ROM), sensory, and reflex changes are, at best, indirect measures of pain. For example, the absence of a reflex does not tell the physician that the patient has pain.[9] No available instrumentation can measure pain directly, especially in terms of quality or intensity. However, electrophysiological parameters may provide good correlation with a patient's report of pain.

There is little consensus between or within specialty groups concerning the use or timing of diagnostic tests to be used in the evaluation of patients with CLBP. X-ray films of the lumbar spine of 40% of individuals who are beyond middle age show evidence of osteoarthritis.[7] Although imaging studies are often thought to be an objective measure of pathology, they often show low specificity.[10,11] Magnetic resonance imaging (MRI), as well as other commonly used diagnostic procedures of the lumbar spine (eg, computed tomographic scan, myelograms), have been found to have a high false-positive rate and they are expensive and/or invasive. A substantial percentage of individuals who have never experienced LBP have abnormal myelograms (24%), computed tomographic scans (36%), MRI scans (30%), or discograms (37%).[10] In a previous study, it was observed that 64% of a group of 98 individuals under the age of 60 with no LBP had a positive finding to some extent on MRI scanning. It was also suggested that false-positive MRI scans might be contributing to increasing rates of low back surgery.[11]

Numerous questionnaires have been useful in the evaluation of the chronic pain patient. The Pain Drawing, McGill Pain Questionnaire, University of Pittsburgh Multi-Dimensional Pain Inventory, Spinal Function Sort Test, and others are based on theories of psychological origin of the pain.[12,13] All of these tests, however, are subjective and cannot be used to prove or disprove a patient's pain complaints.

Surface electromyography (SEMG) is a non-invasive method of analysis of the degree of muscular activity and function. It can be used to assess the overall functional status of muscles and can be done simultaneously on identical contralateral muscles in a number of functional conditions. Electrodes are placed on the skin over the muscle group of interest to measure the summation of muscle action potentials at the skin surface. These collective action potentials are reflected by the measured electric potentials generated by muscle as they contract. In a number of chronic pain syndromes, including CLBP, elevated levels of muscle tension are thought to be a factor. In addition, a pain-muscle-spasm-pain cycle may develop, which further increases symptoms.[14–17] Therefore, SEMG may provide information relevant to CLBP by indicating the contractile state of the lumbar skeletal muscle. Additionally, SEMG may provide evidence for the presence of fasciculations, shivering, active motion, and fatigue of skeletal muscle.[18–21]

To date, research assessing the paraspinal muscle activity of CLBP patients by SEMG scanning has produced conflicting results. These contradictory reports in the current research literature and technical limitations of SEMG equipment have prevented this technique from achieving general acceptance in clinical or occupational settings. Recent technological advancement has overcome the previous limitations of data acquisition and processing.[22,23] Possible reasons for conflicting research findings are considered in detail in the Discussion section. One factor in particular that has generally not been considered in previous studies is the significance of body fat in SEMG results on the lower back. More well-designed clinical studies are needed to demonstrate if this technique is a reliable diagnostic tool that should be incorporated into the comprehensive clinical assessment of CLBP patients and into impairment ratings for CLBP.

The overall goal of our research is to determine the accuracy and usefulness of SEMG in the clinical and occupational evaluation of CLBP. The primary objectives of this study were to: (1) gather more data on the relationship between SEMG measurements and CLBP by using a rigorous matching protocol that includes the adipose tissue factor, and (2) determine the reliability and usefulness of this method in the clinical and occupational evaluation of CLBP. This investigation evaluates and compares static and dynamic SEMG reading activities in the lumbar paraspinal muscles between CLBP patients and healthy controls.

TABLE 1
Characteristics of Subjects

	CLBP*	Controls
Age (y)	40.9 ± 8.2†	41.1 ± 7.3†
BMI (kg/m²)	29.4 ± 5.2†	30.1 ± 4.4†
Males (*n*)	22	22
Females (*n*)	8	8
Race	30 white	25 white/5 black
Working status	100% not working	100% working

* CLBP, chronic low back pain; BMI, body mass index (weight in kg/height in m²).
† Mean ± standard deviation.

Moreover, the study assesses whether there is a consistent association between SEMG reading activities and the presence of CLBP.

Methods

Recruitment of Participants

This study included 60 individuals: 30 CLBP patients and 30 control subjects. Demographic data of the 60 participants are shown in Table 1. Each case was matched to one of the controls of the same gender within ±5 years of age. Seventeen were matched to ≤10% difference in body mass index (BMI) and 13 were matched to ≤15% difference in BMI.

Patients. On the basis of the selection criteria below, the charts of 30 CLBP patients were randomly retrieved from a pool of approximately 80 records of patients who had received SEMG. The age range for the CLBP patients was between 24 and 56 years, with a mean age of 40.9. They included 22 men and 8 women. As described in a previous study,[24] the selection criteria for patients (cases) included:

1. LBP that had been present for at least 6 months and had been interfering with the patient's lifestyle
2. absence of central nervous system dysfunction, such as head injury or stroke
3. absence of cancer as a cause of the back pain
4. current subjective symptoms (ie, complaining of some degree of LBP at the time of the evaluation)
5. being clinically evaluated for CLBP by the same examiner and having a static and dynamic SEMG analysis performed by the same person using a standard protocol.

Controls. Non-back pain patient volunteers seen at the same facility or volunteers from the clinical staff participated as healthy control subjects. The controls included 22 men and 8 women, ranging in age from 25 and 57 years, with a mean age of 41. They had no history of CLBP. For 18 controls, the SEMG testing was performed by the same examiner who tested the CLBP patients. The other 12 controls were tested by the author of this article under direct supervision of the above-mentioned examiner to ensure that the testing was done according to the same standard protocol.

SEMG Testing

Unlike needle electromyography (EMG), SEMG is non-invasive and painless. The static scan was performed on the left and right paraspinal regions with the patient standing in a natural and relaxed posture. The dynamic scan was recorded during three full, natural back flexions and re-extensions. Scan results were automatically compared with a normalized database by the manufacturer's computer program.

Static and dynamic SEMG were performed on the 30 controls according to the same protocol used to test the cases. Additionally, six controls were tested a second time, on a different day, by the same examiner who did the first test to assess intra-subject variability. Also, seven controls were tested at different degrees of body bending (90 and 45 degrees) to assess the difference in SEMG activity patterns.

Each control was given a brief description of the procedure and clear instructions for the flexion/re-extension movement required for the SEMG analysis, and each voluntarily signed a consent form before the testing. The study format and consent form were approved by the Institutional Review Board of the University of Pittsburgh.

The procedure for static scanning was done with three surface EMG electrodes appropriately applied bilaterally to the skin overlying the paraspinal muscle region at level L1 through L5. Lumbar vertebral interspaces were located through palpation by using the iliac crest as a landmark. The static recording was made with the patient in a relaxed standing position. This procedure provides an assessment of the individual's muscle tension as well as postural habits. The patient was instructed to look forward and to maintain the neutral position throughout the scanning. Particular attention was paid to ensure complete contact between electrode and skin at the scanning site, because poor contact can produce erroneously high readings.[21]

The dynamic muscle test involves the assessment of paraspinal musculature function during back flexion/re-extension. Four electrodes were placed symmetrically in the right and left paraspinal region L1 through L5 approximately 3 cm from the vertebral body, in a vertical orientation over the transverse ridge. A ground was placed on the left shoulder. Once the electrodes were in place, the control subject was instructed to perform three natural full flexions of his or her back at a speed resembling ordinary tasks while SEMG recordings were taken.

Equipment

This study used the MyoVision EMG 3000 (PBI/MyoVision, San Carlos, CA), which is currently used routinely at the participating clinic. The device is non-invasive and quantifies the absolute value of the SEMG signal. The actual data are measured in microvolts and represent the amplitude or amount of muscle activity over a time period of

measurement. The instrument uses 20- to 500-Hz bandpass filters. A wideband filter is used to maximize the sequence range and reduce the possibility of false negatives. The range of scanning is between 0.08 and 200 microvolts. Pre-jelled, disposable, self-adhesive 2-cm Ag/AgCl electrodes with sterile conductive medium (PBI MyoVision) were used bilaterally for the dynamic test. Hand-held probes (PBI MyoVision) were used to sample muscle activity at standardized sites in the static scanning. Alcohol wipes were used to clean the skin at the electrode sites, and a razor was used to shave excessive hair from the electrode sites. Antistatic spray (PBI MyoVision) was used on the floor before each reading to reduce the effect of static electricity on the signal obtained. Standard calibration of the device was done on a regular basis according to the manufacturer's instructions. The SEMG testing protocol was in accordance with current guidelines[25–27] (see also Standard of Care Conference, developed by the Congress of Chiropractic State Association). Skin impedance was measured by an impedance meter, with a criterion of less than 50 kΩ established for electrode pairs.[28] The inclinometer, Orthoranger II, was used for the ROM measurements as part of the clinical evaluation on both CLBP patients and painfree controls, according to the AMA Guide to the Evaluation of Permanent Impairment.[7]

Data Processing

The signal was digitally rectified and low-pass filtered, which provided a time-averaged amplitude. An IBM-compatible computer (Pentium, 100 MHz) was used to process the four-channel EMG signal with the software provided by the SEMG equipment manufacturer. The back muscle activity was averaged into EMG numeric values (microvolts) by the computer software. Analysis of the dynamic data was determined by the quantification of the *ratio* of the average peak of three trials of flexion to the average peak in re-extension on both the left and right sides. The dynamic data interpretation also included a visual determination for a possible difference in the shape of the activity pattern (averaged spike potentials) between the patients and the controls.

Data Analysis

Patients and healthy controls were matched for age, sex, and BMI as described previously in the Method section. Data were entered and analyzed by using Minitab Statistical PC software. A series of paired *t* tests was used to evaluate differences in the SEMG activity between the different groups. For the six controls used for the intrasubject test variability assessment, the first test result was used for this analysis. When analyzing total static SEMG values, the readings from both sides from T11 through L5 were combined to arrive to a single total value. Separate comparisons of total right and total left readings were also made. The analysis of the dynamic data included the determination of the averaged left and right ratios of the peak value in flexion to the peak in re-extension. Differences between the calculated ratios were analyzed by using a paired *t* test. Also, a visual determination of the general shape of the curve (spike potential) between the CLBP patients and the controls was made as shown in Fig. 1.

Results

Electric Signal of Back Muscle in CLBP Patients and Controls

Typical static SEMG recordings are shown in Fig. 2 for a healthy control subject (left panel) and for a CLBP patient (right panel). Figure 1 shows typical dynamic SEMG patterns of electric activity for control subjects and patients, respectively, during a flexion re-extension study. As illustrated, the shape of the graphs consistently reflected the calculated ratios between the SEMG activity in peak flexion and peak re-extension. The dynamic SEMG pattern in the non-pain control subjects was characterized by a drop in SEMG activity (in microvolts) when in full flexion (known as the flexion relaxation phenomenon[29])—which was not seen in LBP patients, in whom SEMG activity maintains high values in full flexion (Fig. 1). This visual impression was confirmed by statistical comparison of the ratios described below.

Static SEMG activity in CLBP patients resulted in mean values threefold higher (126.2 μV ± 47.7) than in healthy controls (42.4 μV ± 11.8), with medians of 45 μV for the controls and 110 μV for the CLBP patients. Only one of the 30 patients tested had a total static SEMG result within the mean ± 2 standard deviation range of the controls. Additionally, all of the controls had results within the normal range established by the equipment manufacturer, and all of the patients, with the exception of one, fell in the manufacturer's abnormal range.

In the dynamic analysis, values are expressed as ratio of the mean maximum SEMG level reached in flexion to the mean maximum SEMG level in re-extension. The dynamic SEMG activity showed a twofold higher mean ratio value for healthy controls (2.59 ± 1.04) than for CLBP patients (1.35 ± 0.41). Median values were 3.0 for the controls and 1.0 for the CLBP patients. This result is comparable with that of Sihvonen et al, who reported a ratio of 3.2 in normal subjects and 1.8 in LBP subjects.[30]

A series of paired *t* tests were performed to determine the significance of the difference in SEMG activity in the lumbar paraspinal muscles between patients and healthy controls matched for age, sex, and BMI. As shown in Table 2, there was a statistically significant difference between the two groups, with a P value of <0.00001 for both static and dynamic SEMG comparisons. Significant differences were

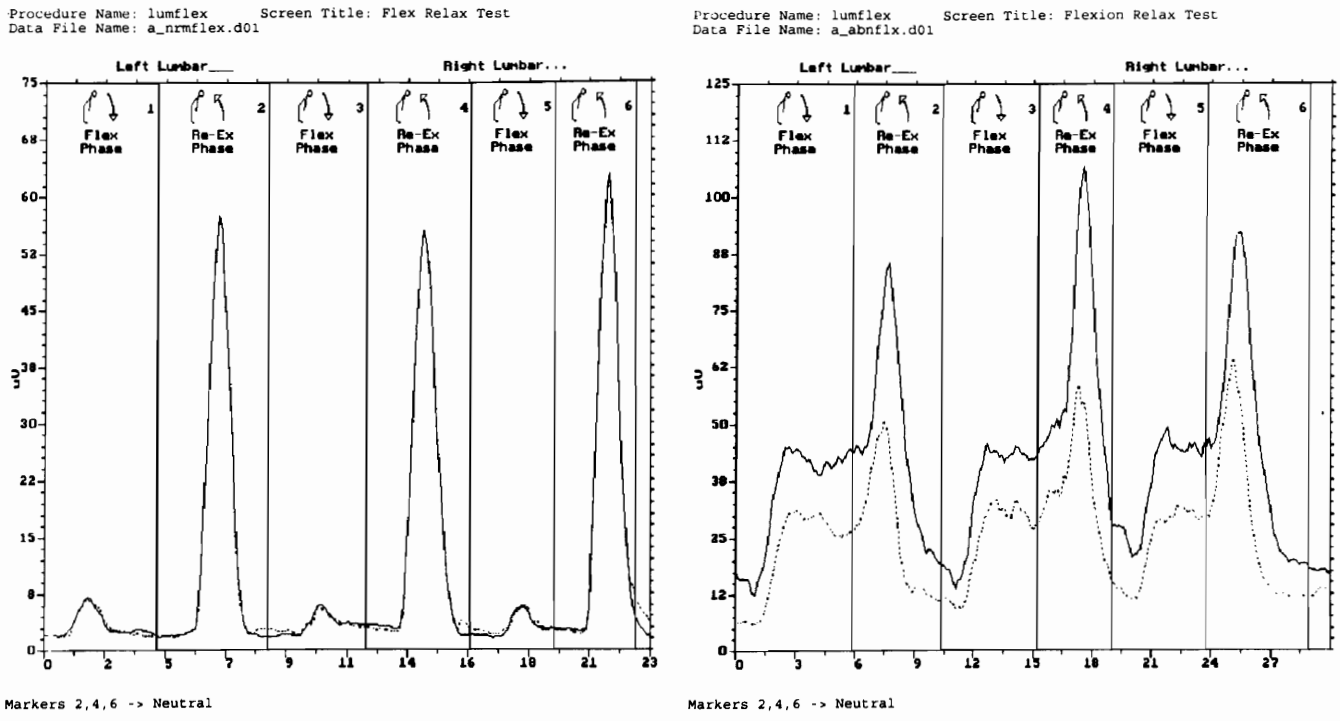

Fig. 1. (Left panel) Typical dynamic SEMG recording of the electric activity (microvolts) in the lumbar muscle region during a flexion and re-extension study on a control subject. There is evidence of a significant drop in the SEMG activity. (Right panel) Typical dynamic SEMG recording of the electric activity (microvolts) in the lumbar muscle region of a CLBP patient. When the patient is in full flexion, there is no evidence of a significant drop in SEMG activity.

also found when paired *t* tests were performed separately for left- and right-side totals in static SEMG analysis (Table 3).

Analysis of SEMG Activity by Gender

The same paired *t* test analyses were performed separately for matched men and women. Results are shown in Table 4. When genders were analyzed separately, the static and dynamic studies were statistically significant for both sexes. Although still statistically significant, the P value for women was higher than for men; however, the sample for women was limited to eight pairs.

Intrasubject Variability of the SEMG Signal

The static and dynamic SEMG variability were compared for six healthy control subjects. A paired *t* test was performed on each set of data. Results are shown in Table 5. The six controls were evaluated on two separate days after exactly the same protocol for both static and dynamic analysis. The level of variability was very low in both tests, as reflected by the high *P* value.

Variability of the SEMG Signal With Different Degrees of Flexion

SEMG signal was measured in seven healthy controls at 90 degrees and 45 degrees of trunk flexion. As indicated in Table 6, a difference in SEMG activity was detected, with a mean reading twofold higher with full flexion.

SEMG Activity and Smoking in CLBP Patients

An unpaired *t* test was performed to assess the relationship between smoking and SEMG electric activity in CLBP patients. As shown in Table 7, smokers had a higher mean static SEMG reading compared with nonsmokers at a borderline statistically significant *P* value of 0.053. No statistically significant difference was found in the dynamic SEMG measurements ($P = 0.47$).

SEMG Activity and Back Surgery in CLBP Patients

Table 8 shows a comparison of the SEMG signal in patients who had a history of back surgery and patients without back surgery. There were no statistically significant differences in either static or dynamic SEMG comparisons ($P > 0.05$). These results are consistent with the previous report by Ahern et al.[31]

Discussion

In their extensive review, Nouwen and Bush[32] reporteded that when only well-designed studies were considered, the evidence for higher SEMG readings between CLBP and controls was minimal. Their review identified four studies of resting paraspinal SEMG, of which only one was positive.[33] Interestingly, that study, which reported resting SEMG activity to be higher in CLBP patients than in control subjects, in-

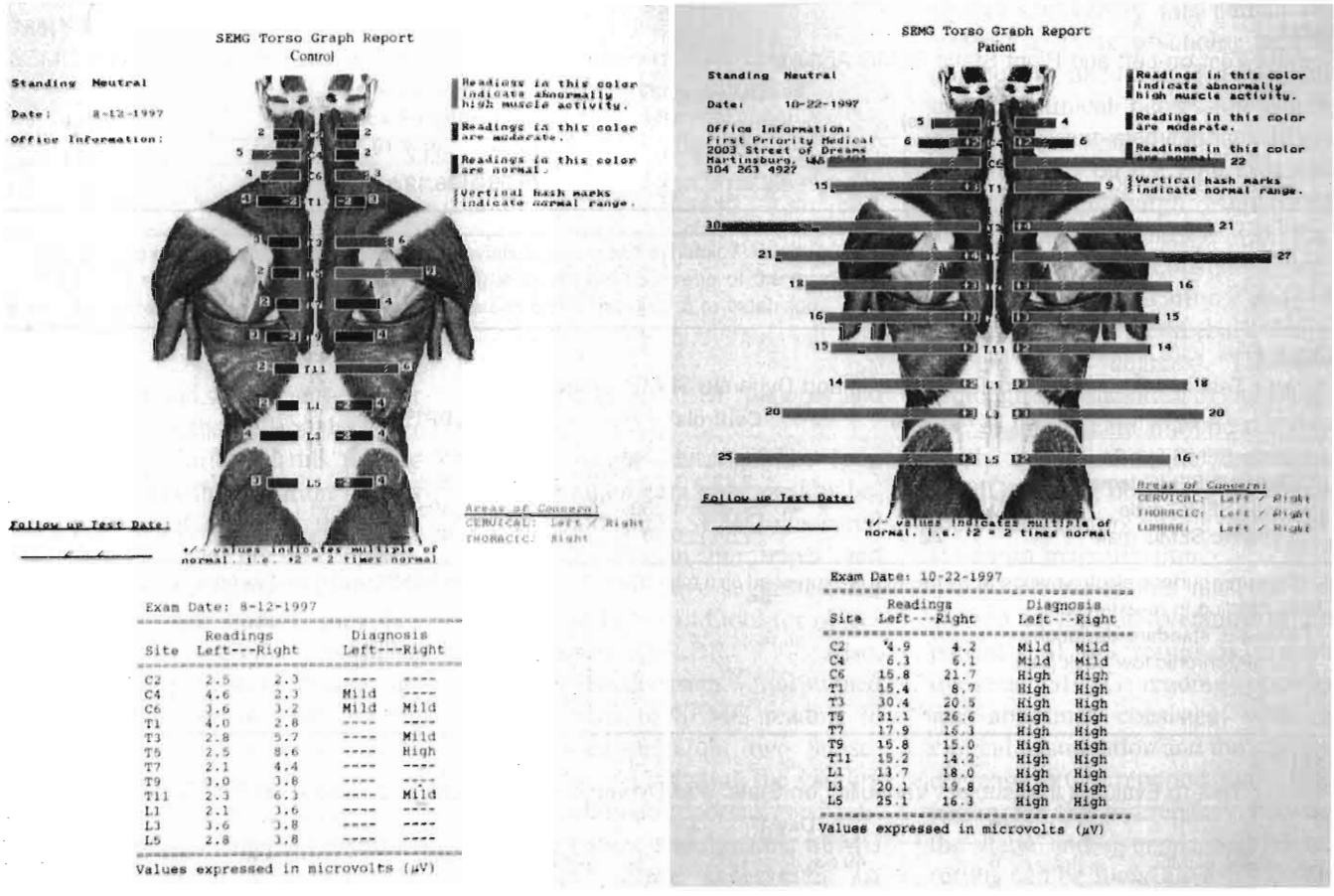

Fig. 2. (Left panel) Typical static SEMG recording of the right and left paraspinal regions in a healthy control. The subject is standing in a natural and relaxed position. Testing is performed according to the protocol described in the Methods section. (Right panel) Typical static SEMG of the right and left paraspinal region in a CLBP patient. The patient is standing in a natural and relaxed position. Abnormally high muscle activity is detected in the paraspinal region under evaluation.

TABLE 2
Paired *t* Test for Static and Dynamic SEMG* Activity Between CLBP† Subjects and Controls

	n (pairs)	Controls†	CLBP†‡	*t*	*P* Value
Static SEMG	30	42.4 μV ± 11.58	126.2 μV ± 47.7	9.12	0.00001
Dynamic SEMG	30	2.59 ± 1.04	1.35 ± 0.41	5.59	0.00001

* Dynamic surface electromyography (SEMG) is expressed as a ratio of the maximum mean SEMG reading in flexion to the maximum mean SEMG reading in re-extension.

† Mean ± standard deviation.

‡ CLBP, chronic low back pain.

cluded a matching protocol for age, sex, *and* body fat, in contrast to the protocols of the other three (negative) studies[34,35] (see also Wilfling FJ, Psychophysiological Correlates of Low Back Pain [Unpublished dissertation], University of British Columbia; 1981). After the Nouwen and Bush review, another negative study that used a matching protocol for age and sex only was published.[24] The importance of controlling for body fat in studies of SEMG in CLBP has generally been overlooked. In fact, our extensive English language literature review identified only one additional study comparing SEMG activity of CLBP patients and controls that included matching for not only age and gender, but also for percentage of body fat.[36] This was surprising because it has been demonstrated that thickness of the adipose tissue may account for alteration of up to 20% of the SEMG signal in the resting muscle and 15% in active muscle.[23,37]

In contrast to the primarily negative studies available for the Nouwen and Bush review, Arena et al[38] subsequently compared five LBP diagnostic groups (spondyloarthritis, intervertebral disk disorder,

TABLE 3
Paired *t* Test on Left and Right Static SEMG Activity*

	n (pairs)	Controls (μV)†	CLBP (μV)†	*t*	*P* Value
Left static SEMG	30	18.94 ± 4.38	45.49 ± 23.7	5.83	0.00001
Right static SEMG	30	22.81 ± 7.79	79.06 ± 38.42	7.63	0.00001

* SEMG, surface electromyography; CLBP, chronic low back pain.
† Mean ± standard deviation.

TABLE 4
Paired *t* Test in Males and Females for Static and Dynamic SEMG* Activity

	n (pairs)	Controls†	CLBP†‡	*t*	*P* Value
Static SEMG female	8	47.32 μV ± 11.35	91.93 μV ± 38.9	2.68	0.031
Dynamic SEMG female	8	2.73 ± 1.22	1.5 ± 0.56	2.67	0.032
Static SEMG male	22	40.65 μV ± 11.39	138.92 μV ± 44.76	10.43	0.0000
Dynamic SEMG male	22	2.54 ± 0.99	1.30 ± 0.35	4.81	0.0001

* Dynamic surface electromyelography (SEMG) is expressed as a ratio of the maximum mean SEMG reading in flexion to the maximum mean SEMG reading in re-extension.
† Mean ± standard deviation.
‡ CLBP, chronic low back pain.

TABLE 5
Paired *t* Test to Evaluate Intrasubject Variability on Static and Dynamic SEMG* Activity Collected on Two Separate Days

	n	Day 1†	Day 2†	*t*	*P* Value
Static SEMG	6	49.53 μV ± 15.52	41.15 μV ± 9.63	1.70	0.15
Dynamic SEMG	6	1.43 ± 0.87	2.36 ± 0.92	1.44	0.21

* Dynamic surface electromyelography (SEMG) is expressed as a ratio of the maximum mean SEMG reading in flexion to the maximum mean SEMG reading in re-extension.
† Mean ± standard deviation.

TABLE 6
Dynamic SEMG Measures* With Different Degree of Flexion-Control in Subjects

	SEMG Reading	
n	90°	45°
7	2.87 ± 0.89	1.10 ± 0.23

* Surface electromyelography (SEMG) measures: mean ± standard deviation of the ratios of the peak value in flexion and re-extension. Dynamic SEMG is expressed as a ratio of the maximum mean SEMG reading in flexion to the maximum mean SEMG reading in re-extension.

TABLE 7
SEMG Readings in CLBP Patients by Smoking Status*

SEMG	Smoking (*n* = 11)	Non-Smoking (*n* = 19)
Static‡	147.0 μV ± 38.4	114 μV ± 49.2
Dynamic§	1.28 ± 0.28	1.4 ± 0.47

* Values are expressed as mean ± standard deviation.
† Dynamic surface electromyelography (SEMG) is expressed as a ratio of the maximum mean SEMG reading in flexion to the maximum mean SEMG reading in re-extension.
‡ $P = 0.053$.
§ $P = 0.47$.

unspecified musculoskeletal backache, combined back pain, other back pain) and painfree control subjects during the following six positions: standing, bending from the waist, rising, sitting with back unsupported, sitting with back supported, and prone. They found that SEMG readings can differentiate among different categories of LBP as well as between those with and without LBP. These researchers pointed out that previous studies comparing SEMG activity between CLBP subjects and painfree controls have arrived at conflicting results possibly because of failure to measure subjects in different positions *and* to categorize different types of back pain. They showed that non-pain controls had significantly lower SEMG patterns when compared with patients who have intervertebral disk disorder and unspecified musculoskeletal backache. Moreover, when in the sitting-with-back-support position, the group with intervertebral

TABLE 8
SEMG Reading in CLBP Patients With and Without History of Back Surgery*

	Patients With Back Surgery (n = 9)	Patients Without Back Surgery (n = 20)
Static	120.2 μV ± 49.5	128.29 μV ± 49.1
Dynamic†	1.49 ± 0.48	1.30 ± 0.39

* Values are expressed as mean ± standard deviation. Static and dynamic P Values >0.05.
† Dynamic surface electromyelography (SEMG) is expressed as a ratio of the maximum mean SEMG reading in flexion to the maximum mean SEMG reading in re-extension.

disk disorder had significantly higher SEMG activity than all of the other groups. They attributed this finding to the fact that this position creates the most actual stress to the spine and therefore the greatest muscle tension in that diagnostic group. In this and in later studies, they observed and discussed the importance of clearly differentiating between diagnostic categories of LBP and the utility of measuring subjects in several various positions.[39–41]

Other investigators have also found that SEMG patterns are different in LBP patients compared with controls during flexion.[42] They have suggested that patients with LBP flex their backs differently than those without pain, possibly flexing from the hips while keeping the spine extended, which results in increased paraspinal SEMG activity. Cram and Steger demonstrated that a postural disturbance could be a contributing factor in CLBP.[43]

Other studies have also shown that patients with LBP have increases in absolute SEMG activities in the lumbar paraspinal muscles during motion.[30] Moreover, a significant decrease in SEMG levels has been reported in patients with CLBP after therapeutic osteopathic manipulation.[44–46]

It should be noted that some of these positive studies have been criticized for: their failure to normalize the SEMG data, their use of questionably high band-pass filters to attenuate noise artifact, their use of only a few electrodes not properly applied, their failure to report intrasubject variability, and their poor or no matching of CLBP patients and controls.[22,23,32]

More recent investigations have found a significant relationship between pain and SEMG-measured muscle activity in the upper and lower back and have suggested that SEMG can be a valid tool for objectively assessing LBP.[36,47,48] Also, although Biedermann[49] questioned the reliability of SEMG reading in biofeedback research, two subsequent studies addressing the validity of this technique reported good reliability for static and dynamic SEMG activities in the assessment of CLBP.[31,50]

By using a rigorous matching protocol that included BMI, our study demonstrated a statistically significant difference between CLBP patients and painfree controls. Thus, the results of this study support the previous investigations suggesting that SEMG is a useful diagnostic tool in the assessment of CLBP.[36,43,44,48] Furthermore, in this study the use of one of the latest and more technologically advanced SEMG devices available has contributed to a more reliable collection and processing of data, giving more strength to this analysis.

Among the 30 CLBP patients in this study, only one had a static SEMG reading within the mean ± standard deviation range of the controls. The chart and clinical examination notes of this patient were thoroughly reviewed. The fact that this patient had a BMI of 41.7, the highest among the 30 CLBP subjects evaluated, could explain the low SEMG reading obtained.[23,37] Other factors concerning this patient that suggest a strong psychological pain component include: (1) a long history of clinical depression (taking anti-depressant medications), (2) elevated scores on the Pain Disability Index and Pittsburgh Multidimensional Pain Inventory, (3) Pain Drawing results consistent with symptom magnification, and (4) greatly restricted ROM (back flexion limited to 27 degrees). Therefore, although the thickness of the fat tissue in this patient may be the most likely reason for the low static SEMG reading observed, the abovementioned factors raise a question of symptom magnification.

Another factor that must be considered in the interpretation of this patient's SEMG results is that the dynamic SEMG reading obtained was abnormal, consistent with the clinical examination and the severely decreased ROM reported. One explanation for the discrepancy between the static and dynamic SEMG test results can be found in Table 6. The data indicate that the dynamic SEMG signal showed ratio mean values twofold lower with back flexion of 45 degrees, compared with 90 degrees of back flexion. This observation, in agreement with previous studies,[30,51] suggests that the dynamic test is highly dependent on the bending efforts of the individual and is therefore more subject to manipulation by the patient.

Intrasubject variability was another factor addressed in this investigation. In agreement with previous observations,[31,39,41] the data gathered in this study showed a test-retest reliability for both static and dynamic SEMG readings. These results indicate that SEMG testing is a reliable reproducible technique if done with correct protocol.

In addition, the mean value of the static SEMG measurements was threefold higher in CLBP patients versus controls, compared with a twofold difference between the mean values of the ratios in the CLBP patients versus controls in the dy-

namic testing. This supports the notion that static SEMG activity, which is independent of differences in flexion effort/ability, may be a better method than dynamic testing for measuring the functional status of the paraspinal muscles, especially in cases in which symptom magnification and/or malingering may be suspected.

In summary, the results of this study and others[30,31,33,36,39,41,51,52] support the conclusions that: (1) results of SEMG testing should be controlled for percent of body fat; (2) the dynamic test is more subject to variation due to different degrees of flexion efforts and is therefore more susceptible to manipulation by the individual; (3) during the dynamic testing, clear instructions and coaching by the examiner are necessary to ensure that the patient achieves the maximal flexion within his or her capability; and (4) the dynamic SEMG results must be interpreted with caution if the patient cannot flex to 90 degrees.

The present study did not control for the effect of various types of CLBP and/or the effect of positions on the static SEMG activities. In fact, previous reports have shown that SEMG activities are affected by different diagnoses and positions.[38,40] In these investigations, SEMG activities were measured on five different diagnostic categories of CLBP patients and a painfree control group in six different positions, as described in the introduction. One of the main findings indicated that, overall, the controls had a significantly lower SEMG reading than all of the back pain groups in the standing position, in agreement with the results of the present study. However, the aim of this study has been to investigate the reliability of the SEMG technique in differentiating between CLBP patients as a general group and healthy controls. Moreover, this investigation included a matching protocol, which was not used in the above-mentioned study. The findings of this report support the use of static and dynamic SEMG technique as an objective test to assess abnormal paraspinal muscle activity independently of different types of LBP. The effect of position on the SEMG activity was indirectly addressed by the demonstration that different degrees of trunk flexion produced a significant variation in the readings. The importance of following standard protocol, especially in the dynamic testing, cannot be overemphasized.

At the present time, the technological advances of this technique should be combined with more clinical research on its applicability. More research must be done to better explore the sensitivity of this method in the detection of paraspinal muscle dysfunction. Methodological limitations of this study that must be addressed in future investigations are: (1) the need for blinded testing, in which the examiner collecting the SEMG recordings has no knowledge as to whether the individual being tested is a patient or a control; (2) the need to conduct SEMG readings for patients and controls within the same time frame versus using medical records for the CLBP patients as was done in this study; (3) the need to assess the intrasubject variability on a larger number of CLBP patients and painfree individuals; (4) the need to assess whether in CLBP patients there is a correlation between imaging studies and SEMG readings; and (5) the need to determine normative data for obese individuals (BMI $\geq$ 40). If larger and better controlled studies have results consistent with this investigation, recommendations should be made for the inclusion of SEMG testing in the evaluation of CLBP patients.

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