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The value of electromyography of the lumbar paraspinal muscles in discriminating between chronic-low-back-pain sufferers and normal subjects

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Abstract The authors studied the surface electromyographic (EMG) spectrum of the paraspinal muscles of 350 subjects. They were classified by their history as normal ($n=175$), chronic low back pain ($n=145$), or past history ($n=30$). They pulled upwards on a floor-mounted load cell at two-thirds of their maximum voluntary contraction for 30 s, while the EMG was measured from the paraspinal muscles at the L4/L5 level. From the EMG signal the root-mean-square (RMS) was calculated. Power spectrum analysis allowed calculation of the median frequency slope, the initial median frequency (IMF), modal frequency, peak amplitude and spectral width at half peak amplitude (half-width). All of the variables of the chronic group were significantly different from the normal group, except the median frequency slope, RMS slope and mode. Half-width, age and maximum voluntary contraction were shown to be independent predictors of back pain classifica-

tion. Half-width classified the subjects with a sensitivity of 0.65 and a specificity of 0.75.

Keywords Low back pain · Electromyogram · Paraspinal muscle

Introduction

Chronic low back pain is an increasingly common complaint. Over the last few decades it has become an important cause of disability in the western world. Chronic low back pain is a symptom, not a disease, and a lack of objective findings hinders progress towards an understanding of the causes of, and effective treatment

for, the condition. Clinical examination of chronic low back pain sufferers is remarkable for the dearth of objective physical signs. X-rays, computerised axial tomography, magnetic resonance imaging and other imaging techniques, though objective, provide little or no information on the dynamic function of the spine and fail to discriminate between patients and normal subjects [13]. Techniques for evaluating the function of the

paraspinal muscles have been limited by the patients' ability to influence the outcome voluntarily [30].

In recent years the large numbers of publications of electromyographic (EMG) studies of the paraspinal muscles reflects the increasing importance accorded to muscular dysfunction in chronic low back pain. Power spectrum analysis of the electromyographic signal provides an objective and noninvasive method of assessment of lumbar spinal muscle function [7, 18].

Previously electromyography could study little more than the total power of a muscle, i.e., the amount of electrical current. A recent innovation made possible by the advent of more powerful personal computers has been the analysis of the raw EMG data by a Fast Fourier Transformation, which relies on the principal that any complex waveform can be represented by a set of sine waves of different frequencies. The amplitude of each of these sine waves can be plotted against its frequency. When a muscle is loaded over a given period of time the spectrum will usually become compressed in a lower range of frequencies. This can be described by the rate of change of a statistical description of the spectrum, usually mean, mode or median frequencies [7, 18, 19, 32]. The rate of decline of the power-spectrum median frequency has been shown to correlate well with task-endurance time [22]. How metabolic conditions within the fatiguing muscles are related to the spectral changes is not entirely clear, though the rate of change seems to be crucially dependant on the distribution of different fibre types and their relative sizes [18]. Recent work has suggested that the only factor affecting the initial median frequency (IMF) is the conduction velocity of the muscle, which is proportional to the average fibre diameter [18]. Patients with low back pain have been shown to have significantly higher proportion of type IIX (fast twitch glycolytic) fibres than matched controls [18]. This could contribute to their having a different electromyographic spectrum. Greenough et al. devised a technique of spectral colour mapping, which displays graphically how amplitude and frequency change over time and incorporates many of the other

variables [12]. Although these colour maps were good at discriminating between chronic low back pain subjects and controls, the technique was time-consuming and required an expert observer. From this they developed the half-width, which is the mean width of the spectrum at half the peak amplitude averaged over the whole test duration [24]. How this relates to the underlying physiology has not yet been investigated.

Published studies have described many variables that differ between chronic low back pain patients and normal controls. Most of these studies have been small, and some have reported conflicting results. For example back pain subjects have been described as having a higher, a lower or a similar integrated electromyography (iEMG) to normal subjects, although there has been little consistency in methods for loading the paraspinal muscles during testing [2, 6, 29]. Studies that have demonstrated differences between back pain and control subjects and that have attempted to use these differences to differentiate between the two groups are listed in Table 1. There is clearly a need for a large observational study to evaluate these variables, how they differ between chronic low back pain patients and the normal population and whether they can discriminate between patients and controls.

Materials and methods

Subjects

Three hundred and fifty subjects were tested. Subjects were recruited from amongst the staff of a large general hospital, by visiting wards and hospital departments and testing all the members of staff who were willing to participate and by advertising in a hospital newsletter for subjects. Further back pain subjects were recruited from patients attending a spinal-assessment clinic and by contacting members of staff who had time off work due to back pain. Of the subjects, staff accounted for 67%, of whom 22% suffered chronic low back pain. All

Table 1 Published studies on the utility of EMG to discriminate between chronic-low-back-pain and normal subjects (*IMF* initial median frequency, *MF slope* median frequency slope, *iEMG* integrated electromyography)

Author	Year	Number of chronic-low-back-pain subjects	Number of normal subjects	Variables measured	Sensitivity	Specificity	Accuracy
Mayer [22]	1989	10	11	Mean power frequency	0.90	0.36	0.63
Roy [31]	1989	12	12	IMF, MF, MF slope	0.92	0.82	0.87
Biedermann [4]	1991	27	22	IMF, MF, MF slope	0.83	0.4	0.62
Arena [3]	1991	25	20	Volts	0.56	.80	0.68
Klein [16]	1991	8	16	IMF, MF, MF slope	0.88	1	0.94
Cassisi [5]	1993	21	12	iEMG	0.67	0.41	0.54
Roy [32]	1995	85	48	IMF, MF slope, recovery	0.85	0.86	0.86
Greenough [12]	1998	38	61	Spectral colour map	0.76	0.81	0.79
Peach [28]	1998	21	18	IMF, MF slope	0.94	1	0.97

subjects were assessed by a surgeon, and those with clinically identifiable pathology such as disc prolapse, nerve root compression and inflammatory arthritis, or those who had previously undergone spinal surgery, were excluded. Potential subjects with acute back pain on the day of interview were also excluded, as were subjects who had exercised vigorously prior to the test on the day of testing (e.g., those who had cycled to work).

The height and weight of all subjects were recorded. Percentage body fat was estimated with a skin fold calliper [9] and from this the lean body mass was calculated. Subjects were classified as follows according to their history:

- Normal: no episode of back pain sufficient to cause time off work or to prevent activities of daily living in past 5 years
- Chronic: continuous or intermittent pain sufficient to cause time off work or to prevent activities of daily living over last 12 months. At least one episode in the last 3 months. Pain at least 3 out of 10 on visual analogue scale during attacks
- Past history: at least one episode in the last 5 years severe enough to cause time off work or to prevent activities of daily living, but no such attack in the last 2 years

One hundred seventy-five subjects were classified as normal, 145 as chronic and 30 as past history.

Method of acquisition and processing of EMG signal

Isometric lumbar extensor testing

The method used has been previously described by Oliver et al. [27]. With the subject standing a pelvic rest was set 6 cm below the anterior superior iliac spines. The subject was positioned with a trunk angle of 30° flexion using a goniometer. Loading was performed by the subject pulling upwards with straight arms on a bar attached to a load cell fixed to the floor. Maximum voluntary contraction (MVC) was determined as described by Oliver et al. [27], by taking the average of three trials, so long as they were within 10% of each other. After a 4-min rest the test was made with the subject maintaining a load of two-thirds MVC for 30 s while surface EMG was recorded.

EMG recording

EMG recording sites were carefully prepared in every subject, according to the method of Oliver et al. [27]. Surface electrodes were placed bilaterally over the greatest convexity of the erector spinae muscles at the L4/L5 level, with a distance between the electrodes of each pair of 10 cm.

A Medelec 2ME EMG system was used to amplify and filter the EMG signal (band pass 3–300 Hz). The analogue output of the EMG system was digitised on a laptop computer using a National Instruments DAQ-Card-700 PCMCIA analogue-to-digital converter. Two channels of EMG and the output of the load cell were sampled at 1,024 Hz using a continuous double-buffered process, while the acquisition software maintained a real-time bar graph display of load centred at the target load of two-thirds MVC. By using this clear target display, subjects were able to hold a steady load for 30 s very accurately.

EMG analysis

Both channels of the 30-s EMG recording were divided into 1-s epochs of 1,024 voltage samples. The root-mean-square (RMS) voltage was calculated for the whole test period, by rectifying each of the 30,720 voltage samples scaled to EMG amplifier gain and taking the mean of these values.

A Fast Fourier Transformation was applied to each epoch to obtain a power spectrum. The median frequency, defined as the frequency that divided the spectrum into two equal areas, was calculated for each epoch. The initial median frequency (IMF) and median frequency slope (MF slope) were obtained from the intercept ($t=0$) and slope of a linear regression fit to the 30 median frequencies calculated for each channel.

The 30 power spectra were averaged and the composite spectrum was smoothed by applying a three-point moving average in three passes. From this the peak amplitude was taken as the greatest amplitude, and the modal frequency was taken as the frequency at which the amplitude was greatest. The half-width was taken as the width of the spectrum at half the maximum amplitude. A few spectra demonstrated a low-frequency spike. If this was present, it was not included in the half-width measurement (Fig. 1).

Statistical methods

Low back pain groups were compared to the normal subjects for anthropometric data and MVC and EMG variables using appropriate *t*-tests. For each of the EMG variables, and for MVC and percentage body fat, sensitivity, specificity and accuracy discriminating between normal and low back pain groups were calculated for every value. Accuracy was defined as the proportion of correct tests, adjusted for different sample sizes in the normal and low back pain groups. Logistic regression was used to consider the predictive value of zdemographic, anthropometric, MVC and

Fig. 1 The half-width was taken as the width of the spectrum at half the maximum amplitude

EMG variables for low back pain. Multiple outcome logistic regression was used to predict chronic low back pain and past history of low back pain simultaneously. A basic model of demographic and anthropometric variables with MVC was built and then each of the EMG variables was introduced into that model separately. Each EMG variable was considered for significance as a predictor of either chronic back pain or past history and based on changes in the model chi-square statistic. Models were assessed for collinearity between predictors. Results of the multiple outcome models can be interpreted as if from two separate models, modelling both outcomes with reference to the normal subjects, controlling for the other outcome.

A jackknife analysis was performed. Each category was randomly split and then assigned to one of two groups. For each EMG variable the value that discriminated most accurately between chronic and normal subjects in the first group was determined. The accuracy with which this value discriminated between

chronic and normal subject in the second group was then calculated.

Results

None of the subjects were unable to complete the test due to back pain (those with pain at the time of interview had been excluded). Men and women were of similar ages within the sample. Anthropometric data is given in Table 2 for men and women separately, with comparisons made between subjects in the two low back pain groups and their peers of the same sex in the normal group. Men and women in the chronic group were older and had a higher percentage of body fat than the normal subjects of the same sex. Women with chronic low back pain were also heavier than the normal women. Among those with a history of low back pain, men had a lower percentage body fat and women were slightly taller compared to their normal peers of the same sex.

The mean values for all seven spectral variables and MVC are presented in Table 3. There was no normalisation of the data and no adjustment for arm length or height. MVC, RMS, IMF, peak and half-width were significantly associated with chronic pain relative to the normal reference group. Only half-width was significantly associated with past history relative to the reference group.

RMS, IMF, peak and half-width all discriminated between chronic low back pain patients and normal controls with an accuracy of greater than 0.6. The values that gave the greatest accuracy are given in Table 4 along with the sensitivity and specificity at that value of the variable. MVC, percentage body fat, median slope and mode all had an accuracy of less than 0.6 and have been included as Table 5. Logistic multiple regression analysis did not demonstrate any combinations of variables that were more accurate predictors than half-width alone. Illustrative sensitivity and specificity curves half-width and median slope are presented in Fig. 2 and 3.

Table 2 Anthropometric data for 350 subjects by sex, with comparisons made within sexes for normal subjects and those with chronic or past low back pain based on appropriate *t*-tests

	Number	Mean age (range)	Height cm (SD)	Weight kg (SD)	Body mass index (SD)	Body fat % (SD)	Lean body mass (SD)
Male subjects							
Normal	61	34(15–62)	177.2(6.22)	78.0(13.05)	24.8(3.94)	20.3(5.45)	61.7(7.87)
Chronic	57	41**(18–65)	178.4(7.19)	82.0(14.10)	25.7(4.15)	23.3*(6.55)	62.2(9.21)
Past history	10	34(20–48)	176.5(6.56)	69.9(7.55)	22.4(2.09)	19.0(7.32)	56.3*(4.74)
Female subjects							
Normal	114	36(17–65)	163.1(6.00)	61.1(9.58)	23.0(3.40)	28.4(5.56)	43.5(5.56)
Chronic	88	41**(19–76)	163.1(6.41)	64.8**(10.61)	24.4**(3.91)	31.3**(5.45)	44.2(5.88)
Past history	20	36(21–56)	166.3*(6.44)	64.8(8.52)	23.5(2.96)	29.7(5.88)	45.4(5.88)

*Significantly different from the normal group for the same sex, $p < 0.05$

**Significantly different from the normal group for the same sex, $p < 0.01$

Table 3 Mean values for maximum voluntary contraction (*MVC*) and EMG spectral variables for 349 subjects, with comparisons for normal subjects and those with chronic or past low back pain based on appropriate *t*-tests (*RMS* root-mean-square, *IMF* initial median frequency)

	Number	MVC (SD)	RMS (SD)	Median slope (SD)	IMF (SD)	Mode (SD)	Peak (SD)	Half-width (SD)
Normal	174	64.9(34.45)	123.99(66.53)	-0.16(-0.23)	46.96(7.73)	35.87(5.97)	481.57(813.94)	38.89(13.50)
Chronic	145	52.1**(27.20)	86.66**(46.25)	-0.13(0.20)	53.18**(9.36)	37.28(8.50)	182.92**(347.29)	53.27**(15.76)
Past history	30	66.9(27.59)	115.0(69.50)	-0.14(0.13)	49.79(8.92)	35.67(7.58)	464.50(976.46)	44.3*(15.52)

*Significantly different from the normal group, $p < 0.05$

**Significantly different from the normal group, $p < 0.01$

Table 4 Sensitivity and specificity of variables discriminating between chronic-low-back-pain and normal subjects with an accuracy of greater than 0.6 (*RMS* root-mean-square, *IMF* initial median frequency, *V* volt)

	Value discriminating chronic subjects	Sensitivity	Specificity	Accuracy
RMS	< 92 V	0.70	0.68	0.69
IMF	> 50 Hz	0.67	0.71	0.69
Half-width	> 48 Hz	0.65	0.75	0.70
Peak amplitude	< 160 V	0.74	0.67	0.71

Table 5 Sensitivity and specificity of variables discriminating between chronic-low-back-pain subjects and normal subjects with an accuracy of less than 0.6 (*MVC* maximum voluntary contraction)

	Value discriminating chronic subjects	Sensitivity	Specificity	Accuracy
MVC	< 52 kg	0.57	0.54	0.55
Percentage body fat	> 27%	0.58	0.61	0.59
Median slope	> 1 Hz sec ⁻¹	0.63	0.41	0.52
Mode	> 40 Hz	0.67	0.18	0.58

None of the variables were able to discriminate effectively between normal and past-history subjects or between chronic-low-back-pain patients and past-history subjects.

In the jackknife analysis of the EMG variables, RMS, peak, IMF and half-width accurately discriminated between chronic-low-back-pain patients and normal controls in the second group greater than 60% of the time. Mode performed less well and MF slope was no better than chance. The results are presented in Table 6.

Examining those subjects who were misclassified, normal controls who were misclassified by half-width, i.e., had half-widths above 48 Hz., were significantly older ($p < 0.01$), shorter ($p < 0.05$), lighter ($p < 0.05$) and had a lower MVC ($p < 0.001$) than correctly classified normal subjects. There were no significant anthropometric

Fig. 2 Sensitivity, specificity and accuracy of median slope discriminating between chronic-low-back-pain subjects and normal controls

Fig. 3 Sensitivity, specificity and accuracy of half-width discriminating between chronic-low-back-pain subjects and normal controls

Table 6 Jackknife analysis. Percentages of subjects in second group correctly classified by discriminant calculated from first group (*RMS* root-mean-square, *V* volt, *MF* slope median frequency slope, *IMF* initial median frequency)

	RMS V	MF slope Hz sec ⁻¹	IMF Hz	Mode Hz	Peak amplitude V	Half-width Hz
Discriminating value from first group	95	-0.25	52	37	180	48
Chronics correctly predicted (%)	77	79	54	47	76	60
Normals correctly predicted (%)	63	15	79	62	64	74
Correct (%)	69	44	68	55	70	67

differences between the back pain subjects who were misclassified and those back pain subjects who were not, though significantly more were female ($p < 0.05$).

In a multiple-outcome logistic-regression model predicting chronic low back pain and history of low back pain separately, age, BMI and MVC were significant predictors of chronic low back pain but were not significantly associated with history of low back pain (Model 1, Table 7). Sex, height, weight and percentage body fat were not significant predictors of either chronic or past back pain when controlling for age. The basic model that included age, BMI and MVC was used to consider each of the EMG variables as predictors of either chronic or history of low back pain (Table 8). When controlling for age, BMI and MVC, median slope and mode were not significant predictors of chronic or history of low back pain. Only mean half-width was a statistically significant predictor of both chronic back pain and history of back pain controlling for age, BMI and MVC in a model that explained 14.6% of the variability in the data (Model 2, Table 7). In the models that included half-width and each of the other EMG variables, only mode was a significant predictor of both chronic back pain and history of back pain (Model 3, Table 7).

Discussion

The results of this study demonstrate that the values of EMG variables in chronic-low-back-pain patients are significantly different from those in normal subjects. All the EMG variables were able to discriminate between low back pain patients and normal controls, though with differing levels of accuracy. None of the variables were able to discriminate effectively the past-history subjects from either the normal controls or the chronic-low-back-pain patients. This may be due to the small size of the past-history group or because the ranges of the past-history group's variables are large with considerable overlap with both the chronic-low-back-pain and normal groups.

MVC and percentage fat

Many studies have demonstrated that the paraspinal muscles are weak in subjects with chronic low back pain [3, 22]. Though MVC is simple and cheap to measure, it is a composite variable dependent on a great many factors including age, gender, height and weight. It is

Table 7 Polytomous logistic regression models predicting chronic low back pain and history of low back pain in a basic model of demographic and anthropometric variables and models that include half-width and mode, for 347 subjects (*BMI* body mass index, *MVC* maximum voluntary contraction)

	Model 1	Model 2	Model 3
	Beta coefficients		
Chronic low back pain			
Age	0.042**	0.027*	0.027*
BMI	0.098**	0.096**	0.084*
MVC	-0.015**	-0.010*	-0.008
Half-width	—	0.060**	0.086**
Mode	—	—	-0.079**
History of low back pain			
Age	0.003	-0.003	-0.003
BMI	-0.058	-0.060	-0.065
MVC	0.003	0.006	0.007
Half-width	—	0.031*	0.055**
Mode	—	—	-0.077*
Model statistics			
Pseudo-R ²	0.073	0.146	0.166
Chi-square	—	46.61	58.86

* $p < 0.05$

** $p < 0.01$

Table 8 EMG variables as predictors of chronic low back pain and history of low back pain, when included separately in basic model of age, body mass index (BMI) and maximum voluntary contraction (MVC). Chi-square statistic compares model with each EMG variable to the basic model, to test for significant improvements in the model of both outcomes (*RMS* root-mean-square, *IMF* initial median frequency, *MF slope* median frequency slope)

EMG variable	Beta coefficients		Chi-square (2° of freedom)
	Chronic lowback pain	History of lowback pain	
RMS	-0.009**	-0.006	8.94*
MF slope	-0.55	0.84	1.43
IMF	0.090**	0.040	37.72**
Mode	0.024	-0.006	2.00
Peak	-0.001*	-0.000	6.28*
Half-width	0.060**	0.031*	46.61**

* $p < 0.05$

** $p < 0.01$

also highly dependent upon the subjects' motivation and cannot, therefore, be viewed as a truly objective variable. The current study demonstrated significant differences in MVC between back pain subjects and control subjects, but it also showed that although MVC is an independent predictor of low-back-pain classification, the accuracy of discrimination was poor.

If an EMG variable is influenced by load to any significant extent, then the results will be, in part at least, dependent on the MVC and, therefore, the subject's volition. Nargol showed that RMS, RMS slope, integrated root-mean-square (IRMS) and median frequency slope are all highly dependant on load [24]. Oddson et al. [26] have demonstrated that a "true" MVC can be predicted from anthropometric data. Mannion et al. have shown that back muscle strength is correlated with body mass and lean body mass [21]. In setting a load based on anthropometric data, however, one must be cautious of asking chronic-low-back-pain patients to lift a weight that they cannot reasonably be expected to manage, whilst still loading the muscles enough to produce meaningful data.

Percentage body fat was also significantly greater in the back pain subjects but, again, was a very poor discriminator. Body mass index has previously been associated with variance of the median frequency slope results [33]. This has been attributed to spatial filtering of higher frequencies, which would reduce the values of variables derived from the median frequency and the half-width [31]. In our data, back pain patients had higher IMFs and half-widths and were also fatter than normal subjects, which suggests that either spatial filtering is not significant or that IMF and half-width would be even better discriminators if correction for spatial filtering could be achieved. Fat percentage was not found to be a significant factor predicting the classification.

RMS

The "power" of the EMG was one of the first variables to be described and is a measure of the amount of electrical potential, measured in micro volts (V). This was originally measured as the number of times a given capacitor was recharged per unit time, but as computing power increased it was calculated as the area under the power/frequency curve, "integrated EMG". RMS is another way of calculating power and is also expressed in micro volts.

That the power of the EMG increases with fatigue has been demonstrated [10], and one study has suggested that the increase is greater in chronic-low-back-pain subjects [17] but again, this study examined only a small number of patients. The EMG was recorded with the subjects lying prone, holding their upper body unsupported. As the chronic-low-back-pain subjects had significantly greater body mass indices, they would have been supporting a greater load and, therefore, are not strictly comparable with the control group.

We found that the RMS was significantly different between back pain subjects and normal controls. It performed well as a discriminator but was highly correlated with MVC and did not independently predict classification. Until the optimal loading of the back muscles during testing can be determined, its utility may be limited.

Mode

The mode failed to discriminate between the groups on simple analysis. However, it was the only variable providing additional information to the model comprising anthropomorphic factors and half-width, providing a slight increase in explained variance. Chronic subjects demonstrated a nonsignificant shift of the spectrum to the right, in the direction observed in fatiguing contractions.

MF slope and IMF

Studies have found MF slope to be a suitable technique for monitoring back muscle fatigue [19]. Much of the recent work on the differences in the EMG of chronic-low-back-pain subjects and normal subjects has focused on the characteristics of this fatigue slope. Roy [32], using the initial median frequency (IMF) and the fatigue slope, was able to achieve a sensitivity of 0.91 and specificity of 0.83. Biedermann et al. [4] have noted methodological shortcomings in this study, including the restriction of assessment to well-motivated subjects, able and willing to generate a reasonable MVC. Klein [16] achieved a sensitivity of 0.88 and specificity of 1

but only studied university rowers, who cannot be considered to be typical of either chronic-low-back-pain subjects or controls. In a subsequent study, Roy et al. achieved a sensitivity of 0.85 and specificity of 0.86. Using a discriminant function derived from a learning group, they were able to correctly classify all six normal subjects and 88% of the 57 back pain subjects in a “hold out” group [33]. Though only data acquired at 80% MVC were used, the mean MVC of the normal subjects in the hold-out group was double that of the learning group, and the mean MVC of the back pain subjects in the hold-out group was lower than in the learning group. This raised the possibility that subjects were being classified by their MVC. Roy et al. tested this possibility by forcing the subjects’ MVC into their discriminant analysis, which remained essentially unchanged. They interpreted this as suggesting that the original results were unrelated to the subjects’ ability to attain a true MVC, though it could also imply simply that the MF slope is very closely correlated with MVC. The current study would support the latter conclusion. Peach and McGill [28] were able to discriminate between back pain subjects and controls with a sensitivity of 94% and a specificity of 100%, using a method similar to Roy’s. Again, their sample size was relatively small and their normal controls much younger than the back pain subjects. Subjects were tested at 60% MVC, though the actual loads are not stated and their back pain subjects appeared to have lower MF slopes than controls in the lower lumbar spine. This suggests that they were less fatigable than controls, in direct contrast to Roy’s subjects.

The change of median frequency with time has been thought to be one of the defining characteristics of fatigue [10]. In the present study it was the only variable for which there was no significant difference between the chronic-low-back-pain patients and the normal controls, and it was shown to be the worst discriminator in our study group, discriminating accurately less than 55% of the time. This could be due to our back pain subjects being tested at loads calculated from their measured MVC, rather than their calculated MVC, and not, therefore, loading their muscles enough to produce useful MF slope data. The average test load for our subjects was 35 kg, only half as much as the test load used by other groups. Oddsson et al. have shown that classifications using the MF slope start to deteriorate significantly below 55% of their predicted MVC, calculated from anthropometric data [26]. This work was done on motivated, young and active subjects who are likely to be able to pull much harder than many of the patients seen in clinical practice, who are often neither motivated, young nor active. If MF slope can only discriminate at loads greater than chronic-low-back-pain subjects can achieve, then this may compromise its diagnostic utility.

We have found IMF to be a variable that is reliable and relatively independent of load [14, 24], though other groups have shown that it is load-dependant at lower loads [20]. It has been suggested that IMF is closely related to fibre size. Mannion et al. found significant differences in the proportions of different fibre types between back pain subjects and controls but not different fibre sizes in a given fibre type. Consequently, how IMF discriminates remains obscure [18].

We found the IMF to be one of the most accurate discriminators, second only to half-width, though again Oddsson et al. [26] were concerned about its ability to discriminate at lower loads. Our multiple regression analysis did not show that IMF was an independent predictor of classification, being highly correlated with half-width.

Half-width

The half-width was found to be the most accurate discriminator, apart from peak amplitude, and in the multiple regression analysis half-width was the only EMG-derived variable that was an independent predictor of classification. Half-width has been previously shown to be a variable that is reliable and relatively independent of load [14, 24]. As fatigue is load-related then the half-width cannot be measuring fatigability alone. Although fatigability of the paraspinal muscles may be significantly different between back pain subjects and normal controls [18], this may not be the only difference. Half-width may be a good discriminator, because it reflects not only how the muscle fatigues, perhaps reflecting fibre type distribution, but also the initial state of the fresh muscle, which may be related to fibre size. Back pain subjects have a greater proportion of type II fibres and more pathological fibres [18], resulting in a large spread of fibre diameters. The muscles of control subjects are more homogeneous in the size of muscle fibres. As conduction velocity is proportional to muscle fibre diameter, the spread of the power spectrum is, therefore, narrower, reflected in a narrower spectral half-width. Though a muscle’s fibre-type composition is largely under genetic control, with appropriate training this can change to some extent [11]. Training can also change the diameters of individual fibres [34] and could result in a more homogeneous set of muscle fibres.

Summary and conclusion

There are statistically significant differences in the EMG variables between chronic-low-back-pain patients and normal controls. Half-width, IMF and peak amplitude demonstrated good discrimination between

chronic-low-back-pain patients and normal subjects. Peak amplitude, however, is highly load-dependant and so may be less useful in subjects who are not strongly motivated.

The median frequency slope, which in previous studies has been shown to be a useful discriminator, failed to distinguish normal subjects from chronic-back-pain patients. This appears to be due to the inability of chronic-back-pain patients to sufficiently load the musculature.

In clinical practice the spectral half-width appears to be a robust and reliable discriminator. This observation in a large clinically relevant data set may provide a direction for the development of a measure for treatment effectiveness and also for future investigations into the underlying physiology.

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