ORIGINAL RESEARCH

Normative Data for Paraspinal Surface Electromyographic Scanning Using a 25–500 Hz Bandpass

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Abstract — A protocol has been previously described for recording surface paraspinal electromyographic (SEMG) potentials at fifteen paired sites (4 cervical, 7 thoracic, 3 lumbar, 1 sacral) using a bandpass (range of sampled frequencies) of 100 - 200 Hz. In this paper, normative data from eighty human subjects are presented using this protocol and a 25 - 500 Hz bandpass. The advantages of a 25 - 500 Hz bandpass are discussed.

Key words: Surface Electromyography, Electromyographic Scanning, Chiropractic, Chiropractic Analysis.

Introduction

Electromyography (EMG) is the process of collecting and recording the electrical potentials associated with muscular activity. Surface electromyographic (SEMG) scanning employs hand-held electrodes which are placed on the skin overlying the muscle tissue being evaluated. When the signal stabilizes, it is recorded by a computer. The electrodes are then moved to the next anatomical site. In practice, paired sets of electrodes are placed simultaneously at variable numbers of corresponding contralateral paraspinal sites along the length of the spine.

Kent and Gentempo[1] described a protocol where 15 paired paraspinal sites were evaluated with normative SEMG data collected from 52 human subjects, using a of 100 - 200 Hz bandpass. Cram[2] has also employed a 100 - 200 Hz bandpass for surface EMG scanning. The 100 - 200 Hz range of sampled frequencies was popularized because it excluded 60 Hz noise, which presented a substantial problem prior to the availability of low noise SEMG equipment. Unfortunately, this bandpass also resulted in the exclusion of a substantial amount of SEMG signal, and was criticized since fatigued muscle produces a considerable signal below 100 Hz.[3] The availability of low noise equipment in the 25 - 500 Hz range coupled with the notch filter to eliminate 60 Hz, however, has overcome the problems of lower frequency bandpass. The purpose of this study was to develop a normative data base for paraspinal SEMG scanning using a 25 - 500 Hz bandpass to increase sensitivity in the lower frequencies, as well as to broaden the range of muscular signals in the higher frequencies.

Materials and Methods

Subjects

Paraspinal SEMG data were collected on 80 chiropractic student volunteers. Potential subjects were screened with a health questionnaire. In order to qualify as subjects each volunteer had to have been free of neck or back pain of greater than 48 hours duration for a period of at least one year, and under chiropractic care for a minimum of three months prior to the study. Any volunteer with a history of spinal fracture, spinal pathology, or known developmental anomalies of the spine was excluded from the study. Criteria for inclusion were not disclosed to the volunteers. Informed consent was obtained from the subjects, consistent with the Human Subjects Committee protocol of Life

Table 1

Descriptive Statistics for Paraspinal Surface Electromyography Microvolt Potentials Collected at 25 through 500 Hz.*

	LEFT				RIGHT			
	Med.	Min.	Max.	Mean(S.D.)	Med.	Min.	Max.	Mean(S.D.)
Segment								
C1	3.25	1.90	8.20	3.80±1.60	3.35	1.30	10.40	3.90 ±1.80
C3	4.10	1.30	11.40	4.40±1.80	3.90	1.40	8.90	4.30 ±1.70
C5	3.70	1.50	9.80	4.20±1.80	3.80	1.60	11.30	4.10 ±1.80
C7	4.40	1.90	10.30	4.80±1.90	4.25	1.50	12.00	4.60 ±2.00
T1	4.10	2.10	16.60	4.90±2.70	4.30	1.80	16.70	4.90 ±2.60
T2	4.30	1.60	18.80	5.00±2.80	4.30	1.50	15.20	5.00 ±2.90
T4	5.65	2.00	17.20	6.50±3.00	5.80	1.80	18.50	6.40 ±3.20
T6	7.75	2.20	21.20	8.40±3.50	7.55	1.60	22.40	8.20 ±3.50
T8	9.00	2.20	25.70	9.60±6.10	8.75	1.50	27.30	9.50 ±4.50
T10	9.25	3.20	22.80	10.00±4.20	9.00	2.60	23.70	10.00±4.30
T12	8.65	2.00	23.30	9.80±4.50	9.60	1.50	20.20	9.80±4.40
L1	8.20	2.00	26.40	8.70±4.10	8.40	1.70	21.60	8.60±4.00
L3	5.65	2.00	14.80	6.10±3.10	5.35	1.80	16.30	6.20±3.40
L5	4.75	1.50	16.30	5.20±3.20	4.25	1.70	17.00	5.30±3.50
S1	3.50	1.20	14.00	4.40±2.70	3.55	1.20	12.80	4.40±2.80

Used with permission. The data is expressed as the median, minimum, and maximum values collected, as well as the mean ± standard deviation for each segment.

* The data collected is derived from 80 subjects.

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College School of Chiropractic. Fifty-nine males and 21 females qualified for inclusion in the study. The males ranged in age from 22 through 48 years (average = 29 ± 5.8), while the females ranged in age from 21 through 45 years (average = 29 ± 7.5).

Protocol

Paraspinal SEMG data were collected from all subjects in the seated neutral position, according to the method of Kent and Gentempo. [1] An Insight 5000 EMG was used to collect and process the data (EMG Consultants, Inc. Paterson NJ).

Table 2

Differences in Surface Electromyographical Microvolt Potentials Between Different Anatomical Regions*

	Cervicals	Thoracics	Lumbars	Sacrum
Mean ± S.D.	4.3 ± 1.8^{+}	7.7 ± 3.7	6.7 ± 3.6	4.4 ± 2.8^{+}

* Mean values in microvolts, ± standard deviations, were compared for all anatomical regions recorded using a two tailed Student's t-test assuming unequal variances.

\+ The cervical region and the one sacral segment were both statistically different ($P<0.05$) from the thoracics and lumbars, but not from one another. Likewise, the thoracics and lumbars did not differ statistically from one another.

Results

The 15 paraspinal sites included 4 cervical, 7 thoracic, 3 lumbar, and 1 sacral locations. Table 1 presents descriptive statistics showing the pattern of values received for the 80 subjects. SEMG potentials were measured in RMS microvolts. The median, minimum, and maximum SEMG microvolt potentials collected between 25 - 500 Hz for each paraspinal site revealed a range of values between the 15 different locations. However, median values for right versus left at any given location were separated by less that one microvolt.

Table 1 and Figure 1 display the mean and standard deviation for the right and left side microvolt potentials for each segmental recording site. A two tailed t-test ($p<0.05$) assuming unequal variances revealed no significant differences between the two sides, when all 15 sites were considered, or between corresponding R-L sides for each anatomical region. When microvolt potentials were assessed between anatomical regions, by the same statistical approach, differences were apparent between the cervicals, in regard to the thoracic and lumbar segments studied. Statistical differences were also observed between the thoracic and lumbar segments and the sacrum (Table 2). Mean microvolt values were greatest in the thoracic segments (7.7 ± 3.7) and the lumbar region (6.7 ± 3.6), followed by the cervicals (4.3 ± 1.8) and the one sacral segment (4.4 ± 2.8).

Discussion

This study evaluated the differences in SEMG potentials with two types of band pass filtering. While Kent and Gentempo[1] and Cram[2] first reported data filtered with a 100-200 Hz bandpass; the present study utilized a broader range (25-500Hz). This broader range was investigated because of concerns that the

Figure 1

Figure 1. The mean ± standard deviation is depicted for each segment from which surface electromyographic data was collected. All values are expressed as microvolts. The data is derived from 80 subjects.

original low pass cut-off may have excluded signals important for muscle fatigue, and/or that the high pass cut-off may have excluded significant EMG activity. For example, previous study involving the 100-200 Hz bandpass, showed substantially lower microvolt potentials recorded in the same anatomical regions as currently investigated. This suggests that considerable activity is overlooked when the more narrow bandpass (100-200 Hz) is utilized. Future study will evaluate the clinical significance of this finding.

Average SEMG potentials were essentially the same in both the cervical and sacral regions. A similar phenomenon, but greater magnitude of signal, was also observed in the thoracics and lumbars. The difference in magnitude of the two groups may be explained by muscle mass, orientation of muscle fibers, difference in the ratio of heavy chain myosin isoforms, and differential activation of nervous system pathways. The grouping of anatomical region potentials as well as the difference in signal intensity between regions may be partially explained by the physiology of the spinal musculature. In that regard, other investigators have shown that muscle fibers may be functionally classified as fast twitch and slow twitch fibers.[2] The fast twitch fibers control phasic or fast ballistic movements. Slow twitch fibers are responsible for maintaining tonic postural support. However, the erector spinae muscles present some unique histological and physiological characteristics. One unusual characteristic is that the slow twitch (Type I) fibers are larger in cross section than the fast twitch (Type II) fibers. The large fibers may be recruited at lower forces than the smaller fibers, which is an unusual recruitment pattern. Furthermore, the erector spinae muscles are composed of separately innervated, independently contracting discrete muscle fascicles. The erector spinae muscles rarely shorten beyond their length in the upright standing position. These factors must be considered when assessing SEMG patterns in the erector spinae.[3]

In light of the increased muscle mass and orientation of fibers in the thoracic and lumbar regions, it is not surprising that an increased signal would be detected in those areas when compared to the cervical and sacral areas. The lower frequency potentials produced by the erector spinae may have contributed to the overall greater intensity of signal found in the thoracics and lumbars.

Neurological function also affects SEMG potentials. Bullock-Saxton, Janda, and Bullock[4,5] have used SEMG techniques to assess subconscious and automatic responses in muscle activation patterns. Janda[6] has suggested that good function of peripheral structures, good muscle balance, and activation of the spinocerebellar vestibular circuits facilitates the most important afferent pathways and centers.

Whatmore and Kohi[7] described an important neurophysiologic factor in functional disorders which they termed "dysponesis." Dysponesis refers to a reversible physiopathologic state consisting of errors in energy expenditure, which are capable of producing functional disorders. Dysponesis consists mainly of covert errors in action potential output from the motor and premotor areas of the cortex and the consequences of that output. These neurophysiological reactions may result from responses to environmental events, bodily sensations, and emotions. The resulting aberrant muscle activity may be evaluated using surface electrode techniques.

The concept of dysponesis, and its assessment, has relevance to traditional chiropractic analysis which includes examination of the paravertebral tissues for "taut and tender" muscle fibers. This study has demonstrated that left-right symmetry of paraspinal tone is the rule. Therefore, asymmetrical tone indicates abnormality. D.D. Palmer expressed the relationship between "tone" and the dynamics of health and disease: "Life is an expression of tone. Tone is the normal degree of nerve tension. Tone is expressed in function by normal elasticity, strength, and excitability...the cause of disease is any variation in tone."[8] Evaluation of paraspinal muscle dysfunction is generally accepted as a method for assessment of the neurophysiological component of the vertebral subluxation complex.[9, 10] Segmental asymmetries and alterations of the overall pattern of paraspinal SEMG potentials are associated with vertebral subluxation,[11] which may result in dysponesis.

Conclusions

Three factors are considered in the interpretation of SEMG scans:

1. Amplitude. This refers to the signal level in microvolts. The higher the signal level, the greater the extent of the paraspinal muscle activity. By comparing these readings to a normative data base, elevated or decreased signals can be identified.

2. Symmetry. This refers to a comparison of the left side to the right side.[11]

3. Frequency. Fatigued muscle exhibits a shift in frequency to a lower mean or median frequency, than non-fatigued muscle.[12, 13, 14, 15, 16]

Consistent protocols must be followed to obtain clinically useful information. Amplitudes are comparable only when there is consistency of electrode size, electrode placement, electrode spacing, bandpass, and signal processing. Using information gathered from these factors, paraspinal SEMG scans, coupled with other assessment data, may support examination findings in determining the following:

1. Asymmetrical muscular contraction
2. Areas of muscle splinting
3. Severity of any particular condition
4. Aberrant muscle recruitment patterns
5. Dysponesis
6. Responses to dysafferentation
7. Responses to chiropractic adjustments

The readings of the patient being examined may, therefore, be compared to those of the normative population. The number of standard deviations from the normative readings can be used to assess the degree of abnormality. For example, when assessing elevated readings, one to two standard deviations above the mean is considered a mild elevation, two to three standard deviations, a moderate elevation, and greater than three, a severe elevation. This permits assessment of patient progress. The availability of a 25-500 Hz normative data base will enable clinicians to more effectively evaluate paraspinal muscle activity. Further studies may be undertaken to determine the effect of subject athletic conditioning, body composition, age and gender differences on paraspinal SEMG potentials.

References

1. Kent C, Gentempo P. Protocols and normative data for paraspinal EMG Scanning in chiropractic practice. Chiropractic: The Journal of Chiropractic Research and Clinical Investigation 1980; 6(3): 64
2. Cram J. EMG muscle scanning and diagnostic reference manual for surface recordings. In Cram J (ed). Clinical EMG for surface recordings. Volume 2. Nevada, Clinical Resources; 1990
3. Dolan P, Mannion AF, Adams MA. Fatigue of the erector spinae muscles. A quantitative assessment using frequency banding of the surface electromyography signal. Spine 1995; 20(2): 149
4. Bullock-Saxton J, Janda V, Bullock M. Reflex activation of the gluteal muscles in walking: an approach to restoration of muscle function patients with low back pain. Spine 1993; 18(6):704
5. Janda V. Differential diagnosis of muscle tone in respect to inhibitory techniques. Man Med 1992; 6(5): 166
6. Janda V. Treatment of chronic back pain. Man Med 1992; 6(5):166
7. Whatmore GB, Kohi DR. Dysponesis: a neurophysiologic factor in functional disorders. Behav Sci 1968; 13(2):102
8. Palmer DD. The Chiropractor's Adjustor. Portland, Portland Publishing House. 1930
9. Janse J, Houser RH, Wells BF. Chiropractic Principles and Technic. Chicago, National College of Chiropractic, 1947 (reprinted 1978)
10. Schafer RC. Basic chiropractic procedural manual. Arlington, American Chiropractic Association, 1984
11. Gentempo P, Kent C. The role of paraspinal EMG scanning in managing the vertebral subluxation complex. The American Chiropractor 1990; March: 7
12. Mayer TG, Knodraske G, Mooney V, et al. Lumbar myoelectric spectral analysis for endurance assessment. A comparison of normals with deconditioned patients. Spine 1989; 14. 986
13. Moritani T, Muro M, Nagata A. Intramuscular and surface electromyogram changes during muscle fatigue. J Appl Physiol 1986; 60: 1179
14. Moxham J, Edwards RHT, Aubier M, et al. Changes in EMG power spectrum (high-to-low ratio) with force fatigue in humans. J Appl Physiol 1982; 53: 1094
15. Petrofsky JS, Lind AR. Frequency analysis of the surface electromyogram during sustained isometric contraction. Eur J Appl Physiol 1980; 43: 173
16. Rosenburg R, Seidel H. Electromyography of the lumbar erector spinae muscles-influence of posture, interelectrode distance, strength, and fatigue. Eur J Appl Physiol 1989; 59: 104