SEMG Evaluations: An Overview

by

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Abstract
This article reviews the current techniques of surface electromyography (SEMG) assessment. Discussed are static, dynamic and combination assessment techniques and the rational for their use.

Introduction

The purpose of surface electromyographic (SEMG) assessment is to document the activity of muscles under different conditions. As Basmajian (1967) states "electromyography is unique in revealing what a muscle actually does at any moment during movement and postures. Moreover, it reveals objectively the fine interplay or coordination of muscles: this is patently impossible by any other means" (p.22).

As people lie, sit, stand, move, and experience emotions the activity of muscles continually changes in response to the demands of the situation. Several different sources provide signals summating at the motor neuron pool (Basmajian, 1985). These signals come from the brain, joints, and other muscles and are transmitted by nerves. Neurotransmitters at the motor end plate, as well as other biochemicals can affect the signal. As Basmajian (1967) suggests the SEMG signal not only indicates the status of a muscle, but also tells us about the status of the nervous system serving the muscle. Thus the SEMG signal represents the totality of the system; all parts contributing to produce the signal that is seen at that moment.

Evaluation

Evaluation of this complex signal by SEMG techniques may be divided into 3 types: a) static, b) dynamic and c) a combination of these two. The data produced by these techniques is markedly different. Thus today understanding SEMG evaluation involves understanding the purpose of the assessment, the conditions under which the assessment was conducted, and how these conditions may influence the evaluation procedure(s).

Static

There are 2 primary types of static evaluation. One technique examines the muscle under no load (at rest), while the other type examines the muscle under isometric load (increased muscle tension but with no change in the length of the muscle). Both evaluations require the individual to remain motionless as the assessment is conducted. Evaluations may be conducted in numerous positions (i.e., lying, sitting, standing, flexion, extension, etc.).

No Load (Resting) Evaluations

The activity of the muscle while at rest (i.e., sitting) is studied in this evaluation procedure. This examination is usually conducted to determine which muscles are hyperactive. One or more muscles may be evaluated. This information is then utilized to direct relaxation training. A classic example of this use is the early work conducted by Budzinsky (1973) on the role of the frontalis muscle in headaches. Other muscles often evaluated include the forearm extensor and flexor bundles, upper trapezius and paraspinal muscles of the back.

One of the more common SEMG procedures utilized today is the evaluation of the resting levels of tension of the paraspinal muscles. One of the earliest works in this area was by that of Cram and Engstrom (1986), which established a normative database for the resting levels of the various paraspinal muscles while sitting in an unsupported position. Cram (1986) further studied the test – retest reliability of the static assessment procedure using post style electrodes.

Studying 11 different muscle sites of 12 chronic pain patients, he found a median coefficient of r = .83 for all sites.

While initially designed to direct the relaxation training of hyperactive muscles, this type of assessment has evolved so today it is utilized extensively in the chiropractic community. Examination of the current literature shows numerous studies by chiropractors with little contribution from other disciplines. The resting SEMG appears to be used primarily to objectively evaluate the muscular response to various sorts of manipulations (i.e., Keller, 2000; Colloca, 2001) However static evaluation has been criticized for a number of different reasons. Posture appears to play a major role in determining outcome. Meyer (1994) stated that at that time none of the 12 key criteria used to validate a new diagnostic test were met and that the use of thoracolumbar paraspinal scanning EMG as a paraclinical diagnostic test was premature for clinical application. Meyer's criticism needs to be tempered with a note that the comments were based upon a review of 37 articles in the literature, and limited to only works conducted by chiropractors (Triano, 1994).

Other potential uses of resting evaluations are to document the presence of various dysfunctions. The senior author has studied the use of SEMG in the detection of myokymia. Muscles demonstrate a rhythmic contraction pattern that is often visible under the skin (a rippling like effect). This rhythmic contraction pattern is thought to represent the rhythmic bursts of neural activity, which is present in a number of conditions such as multiple sclerosis, brain stem glioma, polyradiculoneuropathy, and chronic nerve compression such as carpal tunnel syndrome (Chu-Andrews, 1986). While this phenomena has been documented in the literature using needle electrodes its documentation using SEMG has not been proven.

Despite the apparent limitations and criticism of static techniques they remain well utilized and the standard of care for the chiropractic discipline. While the use of static resting techniques has primarily focused upon the activity of the paraspinal muscles, this form of investigation may offer potential for the investigation of different neurological problems.

Isometric (Load) Evaluations

Isometric evaluations are used to study the median frequency (fatigue) of muscles. In this evaluation the muscle is subjected to a constant force load (usually a percentage of the maximum voluntary contraction) in a fixed position. Basmajian (1985) has shown this procedure to be an extremely sensitive indicator of fatigue reacting sooner than root mean square (RMS) values. Since the introduction of this work, these techniques have been replicated and studied to the point that the evidence is overwhelming to support the use of this technique as a measure of muscular fatigue.

Dynamic

The electrical activity of the muscle (measured in microvolts) has a curvilinear relationship to the amount of force generated when analyzed using root mean square (RMS) procedures. This relationship is curved at the extreme ends of movements (little force and extreme force) while it is linear during the remainder of the movement. Studying the linear part of the relationship forms the basis for dynamic evaluations, allowing for the examination of the interactions of muscles within certain limitations. Torque and paralysis may be defined as the summation of electrical activity of muscles about a joint (Basmajian, 1985). For example in the wrist, the wrist flexors and extensors interact to move the wrist. An increase in activity in the extensors greater than that of the flexors causes the wrist to deviate into extension. Flexion of the wrist involves the opposite pattern of activity (flexors greater than extensors). As the imbalance becomes greater the torque (force or speed of the movement) becomes greater. An equal amount of force about the joint leads to no movement or paralysis. Thus dynamic evaluations appear to be particularly suited for examination of torque and paralysis.

Initially dynamic evaluation procedures followed the static procedures and involved comparison of the paraspinal muscle activity across the spine. The primary movement of the targeted muscle was selected for studied. For example, the lumbar paraspinals were studied during flexion and extension of the torso. More recently SEMG protocols have been developed to monitor activity throughout the body. Procedures have been designed to document the presence of muscle imbalances, cocontractions, fasciculations, trigger points and other problems.

Imbalances/Trigger Points

Dynamic evaluations first appeared in the literature in the 1980’s with the works of Wolf (1978, & 1982). They compared the activity of the paraspinal muscles during flexion/extension movements, noting the relationship between the presence of muscle imbalances to that of reported pain. They reported that pain was associated with a difference in level of activity in the paraspinals when compared from side to side. Donaldson (1990) reported that pain was associated with a 20% difference in levels of activity in the paraspinals. Donaldson also reiterated what Wolf (personal communication) had previously stated "symmetrical movements (flexion/extension) should show symmetrical patterns of activity, while asymmetrical movements (i.e., rotation) should show asymmetrical patterns of activity". In 1995 Donaldson demonstrated that trigger point activity was successfully predicted 80% of the time, when examining the sternomastoids and cervical paraspinals for imbalances. Using dynamic evaluation procedures

Since that time the area of muscle imbalances has been extensively examined with the majority of the muscles in the body studied. This field has developed to the point that textbooks (i.e., Cram, 1998) are now available. When combined with the works of Travell & Simons (1983) on trigger points, this area of study has exploded.

Recently Sella (2000a) has developed a series of protocols to study the presence of muscle activity in the various parts of the body. His works are extensive enough to allow for the development of a database and standardized evaluation procedures.   Sella (2000b) also established sensitivity and specificity values for SEMG measurements. While his works need to be replicated, they offer a direction for the future and dynamic evaluation procedures.

The development of dynamic techniques has expanded the treatment protocols available to the practitioner. While static evaluations are designed to highlight the hyperactive muscle, a muscle imbalance has both hyperactive and hypoactive components. Relaxation training and stretching techniques may be utilized to down train the hyperactive muscle, while uptraining techniques may be used to increase the activity of the hypoactive side. The choice is a reflection of the individual practitioner's training.

Reliability

Sihvonen (1991) has studied the reliability of the peak amplitude of the SEMG signal during movement. Examination of the test-retest reliabilities from the lumbar paraspinals during flexion and extension showed r = .92 for flexion and .97 for extension. This meets or exceeds recognized standards of acceptability.

Cocontractions

Cocontractions are defined as an increase in electrical activity of a muscle that should be electrically quiet during a particular movement. SEMG techniques are presently the only way to observe this phenomena. Examples of this phenomenon are just beginning to emerge in the literature. Skubick (1993) while studying carpal tunnel syndrome demonstrated increased electrical activity was present in the forearm flexor and extensor bundles, during movement of the head. He went on to demonstrate that this activity disappeared with correction of muscle imbalances in the sternomastoids. What is striking about this study is that he also demonstrated that pre-treatment nerve conduction studies clearly meeting the criteria for carpal tunnel returned to normal, without treating the arm, but by treating the muscle imbalances. Donaldson (2002) also reported cocontractions in his studies of fibromyalgia. During rotation and flexion of the head inappropriate muscle activity occurred in the forearm extensor bundles, gluteus maximus and vastus medialis.

Basmajian (1985) and Leonard (1990) briefly note this phenomenon in the literature. Basmajian noted that cocontractions occur during periods of stress, illness and cold and with aging. Leopold reported that children showed a cocontraction of the tibialis anterior during a patellar tendon tap. This disappeared with normal maturation at about age 5, while it did not disappear in cerebral palsy children.

Cocontractions can only be observed with SEMG techniques. The problem is knowing what muscles to observe as the literature in this field is remarkably weak. Knowledge of myotatic units and engrams will help the evaluation but at this point studying the muscles that the patient reports as sore is about the only routine way to proceed. The soreness is thought to represent overuse of the muscle(s).

Fasciculations

Fasciculations are a phenomena noted by Sella and the senior author. It occurs during movement and is seen as a severely large amplitude spike affecting all tracings. Originally thought to be artifact, the pattern occurs in individuals with certain neurological conditions (Chu-Andrews, 1986). More research is needed on this phenomenon as to date it is only reported in the literature using needle electrodes.

Combination

Static and dynamic assessment procedures may be combined to form a 3rd type of evaluation protocol. In this situation, a baseline resting level is obtained, a movement performed, and then another resting level is obtained. Comparison of the post movement baseline to the pre movement baseline is then conducted with the expectation that these should be the same. An elevation of the post movement baseline indicates continued muscle activity with little time for recovery before the next movement is completed. A poor recovery of baseline may be associated with chronic pain and repetitive strain injury. These assessment procedures are commonly seen in ergonomic investigations.

Validity

The phrase garbage in, garbage out has never been more appropriate than when studying SEMG. All muscles in the body fire all the time, whether at rest or during movement. Knowledge of the anatomy involved, where the muscles are located and the position of the electrode in relationship to the fibers of the muscle establishes validity. Precise locating of the electrodes parallel to and over the belly of the muscle in question allows for an argument of validity. Steven Wolf in a lecture showed a slide of an X-ray taken of electrodes over the lumbar paraspinals. It demonstrated exactly where the electrodes were placed in regards to the muscle. They were directly over top of the muscle, demonstrating validity. While it is not possible to do this every time we place an electrode on a person, it is incumbent to be able to demonstrate that proper procedures were followed according to known physiological principles and anatomical structures.

Conclusion

This paper is intended to present a brief overview of the field of SEMG evaluation. It is not intended to present an in-depth view of the field, but is intended to acquaint the reader with the various techniques and some of the issues pertaining to the techniques. The reader is encouraged to investigate the issues raised in greater depth by following up with the appropriate texts and publications in the field. For more information in these areas contact the Association of Applied Psychophysiology and/or the Biofeedback Certification Institute of America.

SEMG evaluation procedures have evolved to the point that there are a number of techniques available to the practitioner. Static, dynamic and combined procedures produce different types of data to be used for different purposes. Static evaluations illustrate the presence of hyperactive muscles, dynamic evaluation illustrate a number of different problems including muscle imbalances, cocontractions, fasciculations, while a combination of the two techniques may be used to illustrate a poor recovery of baseline.

Each technique has its certain strengths and limitations. It is important that the practitioner is aware of these issues and selects the assessment procedure appropriate for the evaluation. This should then form the basis of the treatment plan.

SEMG assessment techniques continue to be widely used but need more research development and validation. In the last 20 years there has been a tremendous explosion in the study and use of SEMG assessment procedure.

Until these procedures can be extensively validated and replicated other health care professionals will regard the field with suspicion and the SEMG practitioner should use them judiciously.

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