QUESTIONS TO ASK WHEN INTERPRETING SURFACE ELECTROMYOGRAPHY (SEMG) RESEARCH

Dennis R. Ankrum
Human Factors Research, Nova Solutions, Inc.
Effingham, Illinois USA

Surface electromyography (SEMG) is widely used to evaluate muscle activity. In SEMG, researchers attach electrodes to the surface of the skin overlying a muscle and measure the amount of electricity it produces as muscle fibers contract. SEMG can determine which muscles are active, their degree of activity, and how active the muscle is compared to the subject's capacity. It can also be used to estimate muscle force. Properly employed, SEMG assists in evaluating the relative risk of a work task. As articles reporting SEMG results are often used by ergonomics practitioners as guidance in job design, the ability to interpret SEMG research is critical. Problems occur when researchers assume their readers have a greater familiarity with SEMG than actually exists, or when they make any of a number of SEMG-related research or interpretation errors. This paper suggests some questions that should be asked when evaluating a study that reports SEMG data.

EQUIPMENT AND PROCEDURES.

Were all the data from a subject collected on the same day?

The SEMG signal is extremely sensitive to changes in location of the electrodes. Removing and replacing the electrodes, even if carefully done, will cause a different area of the muscle to be sampled.

Was there a waiting period before starting measurements?

To avoid a change in the impedance of the electrode-skin interface, the electrodes should be allowed to stabilize for at least 20 minutes (Marras, 1990).

What measures were taken to avoid crosstalk and noise?

Nearby muscles can send signals that corrupt the signal of the muscle being studied. This is especially likely when the nearby muscles are being strongly exerted. Some researchers measure the signal from adjacent muscles to see if the signal from the muscle of interest is being contaminated by crosstalk. The paper should also describe the measures taken to avoid noise.

Were the high and low cutoff frequencies specified?

If frequencies below 10 HZ are not eliminated, artifacts caused by movement will contaminate the data. At the other end of the spectrum, a high frequency cutoff at 350 Hz will capture all but about 5% of the information. The Journal of Electromyography and Kinesiology recommends a cutoff frequency of 10-350 Hz (Solomonow, 1999).

What was the sampling rate?

The appropriate sampling rate depends on the type of information desired. For muscle activity, a sampling rate of twice the high cutoff frequency will suffice. If a spectral analysis will be done to evaluate for fatigue, a sampling rate of four times the highest cutoff frequency will reveal more detail.

How long was the sampling period?

Sampling periods can range from one second every five minutes to continuous sampling for over an hour. No standards have been established for sample duration, but the reader should evaluate the sampling length, given the aim of the study.

Were subjects skilled in the task being evaluated?

More skilled operators typically have less muscle tension than less skilled ones (Hagg & Kadefors, 1996). If the subjects are not skilled in the task, EMG readings may be artificially high and the task may be evaluated as more strenuous than it would be for an experienced worker.

FATIGUE

Is muscle fatigue being measured along with muscle activity?

When a muscle fatigues, the high frequency components of the signal are reduced. Thus, if a pre- and post- work analysis shows a downward shift of the central frequency of the EMG spectrum, it can be inferred that the muscle has been fatigued by the task. The length of the muscle greatly affects the frequency content of the signal – as the length of the muscle fibers increases, the conduction velocity decreases. Thus, it is critical that muscle length remain the same for both the pre- and post-activity tests. Lengthening the muscle would result in a greater indication of fatigue and shortening the muscle could cancel out the effect (Winter, 1996).

Redfern (1992) cautions that fatigue measures may not be reliable if the muscle activity level is below 10% of the maximum voluntary contraction.

NORMALIZATION

Were the data normalized before conclusions were drawn?

Normalization allows the results to be compared across subjects, thus compensating for differences in strength, muscle tone, body fat, muscle geometry and other factors. In order to normalize data for comparison, experimenters get subjects to exert a "maximum voluntary contraction" (MVC) of the muscle being studied. Each subject's MVC measurement is then considered as a reference point of 100% and the other measurements for that subject are converted to a percentage of their MVC.

MVC must be established with the muscle and joint in the same positions as during the experiment. Otherwise, the muscle area under the electrode will change and result in inaccurate data.

If the study reports the results in microvolts without normalizing the data, comparison between subjects is impossible due to individual differences as described above. Also, results reported only as microvolts may mask the fact that conditions are either unacceptably high, or so low as to not present a risk.

Did subjects receive preliminary training on how to achieve maximum voluntary contraction?

Training, involving bio-feedback, will increase the MVC that a subject will be able to exert. Lack of training can make the observed task appear more strenuous, and vice versa. While all researchers do not agree that training is desirable or necessary, it is important to know if it was done. The Journal of Electromyography and Kinesiology will not accept reports in which the subjects have not been trained because the results could be as much as 20-40% less (Solomonow, 1999).

MUSCLE SELECTION

Are the muscles being studied relevant to the work being evaluated?

Researchers often select muscles for measurement because they are easily accessed – they are large, close to the surface, or isolated. The authors should state the basis for the selection of muscles. If the trapezius muscle is measured, it is important to know which part: upper, middle or lower. The upper, or descending portion is most often associated with trapezius myalgia. Within the descending portion, the lower region may be the most relevant as it has a higher concentration of the slow contracting, fatigue resistant Type I muscle fibers which seem to be more vulnerable to static loads (Hagg, 1991).

RESULTS

If the results are reported as a % of MVC, is a graph of the amplitude probability distribution function (APDF) included?

The APDF (Figure 1) is the distribution of the levels of muscle contraction during the observation period. The horizontal axis shows the entire range of muscle activity, from low effort to high effort, reported as "percent of MVC." The vertical axis, or the height of the line, shows the percentage of time that effort level was observed.

The graph can be used to identify the percentage of time that muscle activity was less than a given proportion of the subject's MVC. As seen in Figure 1, the same 50th percentile results can be associated with quite different muscle activity patterns. In example A, the muscle spent more time relaxed than in example B. Example B indicates a much greater variety of muscle activity. In addition to the median, either (or both of) the 10th (static) and 90th (peak) load levels should be reported, depending on the static or dynamic characterization of the muscle activity.

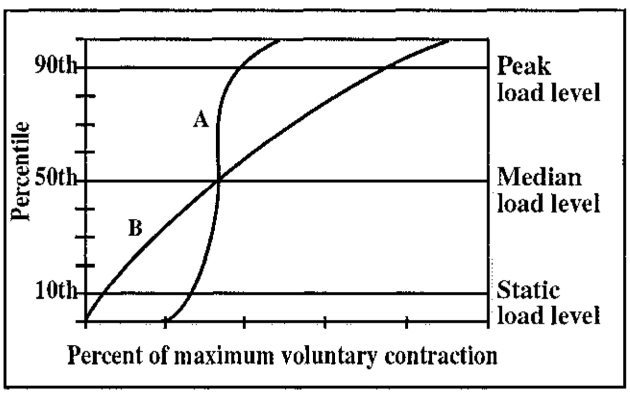

Figure 1. The APDF

What other variables are considered important?

Some researchers consider other EMG variables to more, or just as important as the static load level. Aaras (1994) has proposed that the percentage of time below 1% MVC may be critical. Veiersted, Westgaard, and Andersen (1993) have suggested measuring the number of gaps of at least 0.2s duration under 0.5% MVC. Hagg (1991) states that, for normally statically loaded muscles, the duration of the load and the pauses are the critical factor. Westgaard (this volume) states that three physical dimensions must be considered: amplitude, duration and repetitiveness (i.e. force variation pattern), in addition to the contributions of mental stress and the variable of individual susceptibility.

EMG AND PATHOLOGY

Does the study draw conclusions about the safety/risk of the work with respect to musculo-skeletal disorders?

Hagg and Kadefors (1996) caution that, with the exception of the descending part of the trapezius, most work related musculoskeletal disorders are not disorders of the muscles, but rather nerves, tendons and ligaments. Caution should therefore be used before directly associating increased EMG activity in a particular muscle with increased risk, because a dose-response relationship may not have been established.

MVC THRESHOLDS

Are the results compared to any statements about acceptable limits?

The most widely-applied limits of acceptability are those proposed by Jonsson (1978). He defines three levels of muscle load (see Figure 1): static, dynamic and peak (all based on the APDF) and suggests limits in cases of continuous work. Jonsson suggests that the 90th percentile MVC of the APDF distribution (which he calls "peak") should not exceed 50-70%. The 50th percentile (which Jonsson calls dynamic) should not exceed 10-14%, and the 10th percentile (referred to as the "static load level") should not exceed 2-5%.

Unfortunately, Jonsson's use of the word "static" in his particular context can be confused with the ergonomic work descriptor "static," which tends to mean work that involves little movement. All too frequently, studies that examine "static tasks" have mistakenly compared the mean or 50th percentile MVC of the static task to Jonsson's "static load level" limit, which is incorrect and results in inaccurate conclusions about the relative risk of the task.

LESS IS BETTER?

Do the authors assume that less muscle activity always means a more desirable condition?

With the possible exception of the career of Lil Abner (a USA cartoon character), who made his living as a mattress tester, every job requires some type of muscle activity. The point of ergonomics is to keep muscle activity at acceptable levels, not to eliminate all muscle activity or reduce it regardless of context. In some cases, higher muscle activity levels are desirable to introduce muscle activity variation, as evidenced by the exercise breaks commonly recommended for sedentary jobs.

QUESTIONS GENERAL TO ALL RESEARCH

In addition to these EMG-specific questions, there are many that should be asked of all research. Because they are so common, a few of them deserve to be mentioned:

For instance, do the subjects represent the population to which the authors wish to apply the results, or (for example) are college students acting as surrogates for data entry clerks or middle-aged factory workers? Also, are the subjects given time to learn to become acclimated to new tools or conditions? If a new tool is proposed, such as an alternative keyboard, it may require days for the subjects to learn to use it with speed and ease. Do the conclusions equate statistical significance with importance? Extremely small differences will be statistically significant if the number of subjects or observations is large enough.

CONCLUSION

Glazed eyes are an "occupational hazard" when reading articles reporting EMG research. It is common for readers to skip over sections they don't understand in order to get to the "good stuff," the conclusion. It is hoped that the questions posed in this paper will assist readers in the critical valuation of EMG research.

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