APPENDIX C

Fine Wire Electrodes

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In general, the fine wire technique for recording EMG is seldom indicated in ergonomics. In instances when the EMG of interest is from specific muscles or when muscles are deeply located in a body segment, recordings using fine wire electrodes are necessary for accuracy. Use of the fine wire technique requires adequate anatomical knowledge and training in the technique of implanting the wires.

This procedure is similar to an injection technique and results in the projection of the two fine wires from the muscle of interest. Electrodes for such recordings were produced originally in the 1960s, and the technique has now widely been accepted (Figure C-1).[1] The electrodes can easily be produced locally in a short time.[2] Although there is certain flexibility in using different gauge wire, some limitations are imposed by needle size, wire fracture rate, and other difficulties.

The conventional technique calls for burning of the ends of the wires to be implanted to remove an appropriate distance of insulation. There are some constraints using this technique in that a residue is produced on the end of the wire, resulting in an oxidation of the conductor. This technique also makes it difficult to ensure there is an equal distance of bared surface on each of the individual wires to be inserted. Mechanical stripping may be used, but the actual cutting may nick the wire, causing weak points. The small size of the wire also makes this technique quite difficult. Abrasion techniques are very difficult to control. Others have suggested chemical stripping of distal ends of the wire, but in that case it is difficult to get ends that are entirely clean, In our experience, the orderable lot of the stripper usually is of such magnitude that product decay is severe before the quantity can be used. A rather comprehensive description of these techniques of wire stripping is included in Loeb and Gans.[3]

Use of the conventional fine wire technique demands that the needle and the prepared wire configuration be sterilized after preparation. Although this may be accomplished with dry heat, boiling water or steam, Basmajian and DeLuca recommend autoclaving at 15 lb/in^2 or approximately 10 N/cm^2 for 30 minutes.[2] Virtually any hospital facility will provide these services usually at minimal or no cost.

Because the technique associated with fine wire electrodes is somewhat dependent on the skill of the user, some persons debate the issues of ease of technique and pain as to whether these factors are considered an advantage or disadvantage of this technique. Some users would maintain that this fine wire technique is easier to use and much quicker than surface EMG. Others find difficulties associated with connection of the fine wires, leading to difficulties in attaining high quality signals.

The choice of attaching these two very fine wires can lead to an arduous procedure. There are three primary means by which electromyographers have attached these wires to their amplifiers. One is by means of a pressure jack, in some cases available on a preampllfier. In another case, screw-on connectors have been used. In this case caution must be exerted that pressure is not so great that the wire is sheared and a fracture results. A third choice is the use of spring connectors that in turn are connected to the amplifier system. The possible configurations are shown in Figure C-2. In all cases, the electromyographer needs to be cautious of electrical interference that can be picked up as result of any of these systems and the ultimate artifact that can be induced into the recording.

Regarding pain, most subjects will report that after the wire insertion little pain exists. Additionally, the subject usually cannot identify the location of the wire embedded in the muscle. Jonsson et al did study the pain factor and reported on the discomfort by needle or by wires with diameters of 50 and 25 microns.[4] He inserted the electrodes in the lateral gastrocnemius muscle of both legs in 27 subjects and checked for bleeding and discomfort at several intervals after insertion. The diameter of the larger wire gave slightly more discomfort than the insertion needles without wires, but the difference was not statistically significant. Ninety-one percent of the subjects reported discomfort with 25 micron wire, and 100% of the subjects reported discomfort with 50 micron wire, but it was common to have discomfort on one occasion but not on another. Common terms to describe the discomfort were throbbing, slight pain, stiffness, and dull or piercing pain. Some bleeding occurred in 64% of the cases with 25 micron

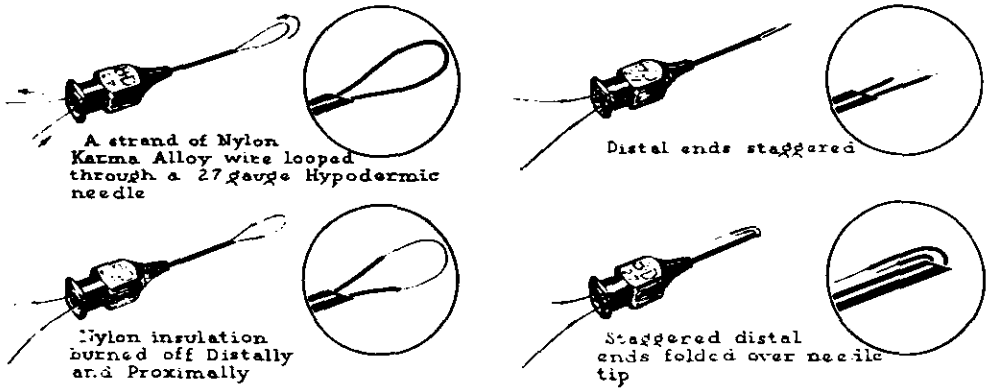

FIGURE C-1

Steps in the production of fine wire electrodes. Hollow core needles of desired length are appropriate.

(Reproduced with permission from Basmajian JV, Stecko G: A new bipolar electrode for electromyography. J Appl Physiol 17:849, 1962.)

wire and in 83% of the cases with 50 micron wire.

Although the fine wire electrodes are very localizing and exact (pickup area approximates 0.01 to 2/10 mm^2), there are difficulties associated with displacement (Figure C-3). Fracture also is a possibility, but occurrence is relatively rare. Furthermore, baring of the distal segments of both wires also creates shorts when these two wires are in contact with each other. The wires also are likely to be sheared as the needle punctures the skin upon insertion of the needle. Finally, the fine wire technique has the potential for physiological responses from the subjects such that shock is induced. This occurs in individuals that are very highly trained and go into further physiologic depression because of an adverse reaction to needle insertion. Although few documented cases of this phenomena exist, the potential result warrants consideration when deciding which electrode technique to use.

Reliability work associated with this technique was done by Jonsson and Reichman who evaluated standard fine wire technique by recording after 5 minutes and after 15 to 20 minutes.[5] They also recorded 3 to 7 days later, labeling muscle activity as slight, moderate, or marked. Results showed that after 15 to 20 minutes, one of the six subjects went from moderate to slight activity; in two subjects, there were slight differences. In reporting various experiments, two subjects had slight differences and one went from slight to moderate. No statistical analyses were applied. Following this work, however, Komi and Buskirk have shown interday reliability coefficients to average between .60 and .81 when considered for tension levels of 20% to 100% of maximum. Work completed on the same subjects by the same authors evaluated the fine wire reliability coefficients and demonstrated an average within-day reliability coefficient of .62 for contractions that ranged from 20% to 100% of maximum. Between-day coefficients ranged from a low of −.05 to a maximum of .55 and yielded an average coefficient of .22 for the same range of contraction strengths. Contributing to the reproducibility problem may be the movement of fine wire electrodes, which has radiographically been shown to be limited to less than 5 mm.[7] The actual effect of these displacements on the reliability coefficient has yet to be determined.

Little information is available as to tissue response with indwelling wire electrodes. Blanton et al studied the initial local effects of wires covered with polyurethane insulation.[8,9] These electrodes were placed into rats, and the tissue was evaluated at 1, 4, 8, 24, 30, 48 hours and at one and two weeks after wire insertion. The results showed that the pattern of acute inflammatory reaction increased in severity

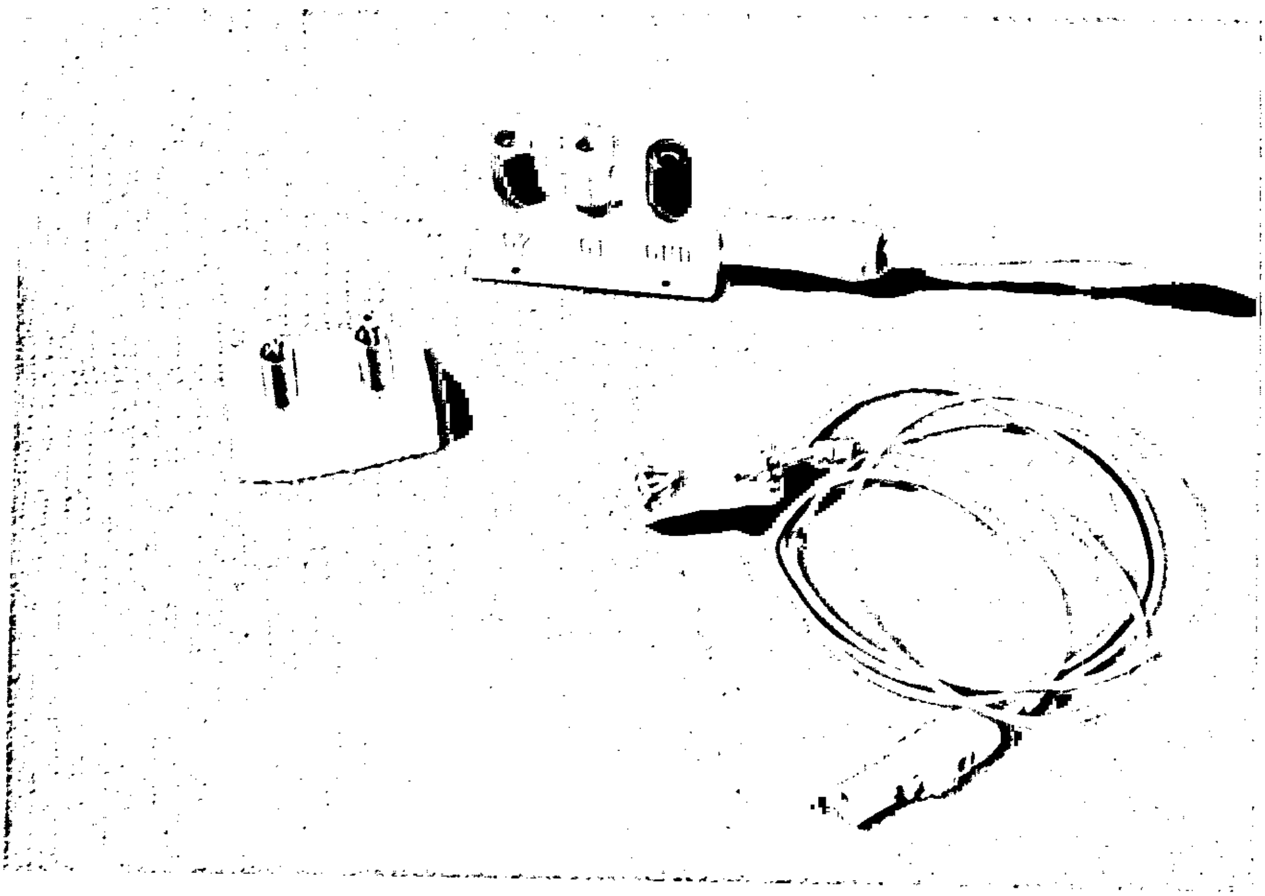

FIGURE C-2
Representative fine wire connection techniques. Wire is inserted into terminal which is then tightened down on wire (upper left). Standard springs may also be used to clamp wire (left). Pressure fitting is available at bottom in which case wire is inserted into the hole in the preamplifier and a pin is inserted.

and focal distance with time, and that after 4 hours, continued inflammation and increase in focal necrosis was demonstrated. The significance of this work is that it apparently is not feasible to leave fine wire implanted intramuscularly for a long term such as several weeks to months. According to the authors, all attempts should be made to record from muscle within 4 hours to evoke the least histologically destroyed response.

After recording with fine wire electrodes, the mechanisms of cleanup are relatively simple. The fine wire ends attached to the connector in use should be disassembled. Then, the inserted wires can be pinched tightly between two fingers and removed with a very mild tug from the examiner. After wiping the subject's skin with alcohol on gauze, the ends of the wires should be examined for completeness. If suspicious that wire fragments are remaining interstitially, the subject should be informed to be aware of residual soreness or for possible signs of infection. Generally, however, fracture of the wires is a very, very slight possibility. Wires should be discarded and the needle broken at the intersection of the shaft and hub. Discarding should be in compliance with rules for sharp materials.

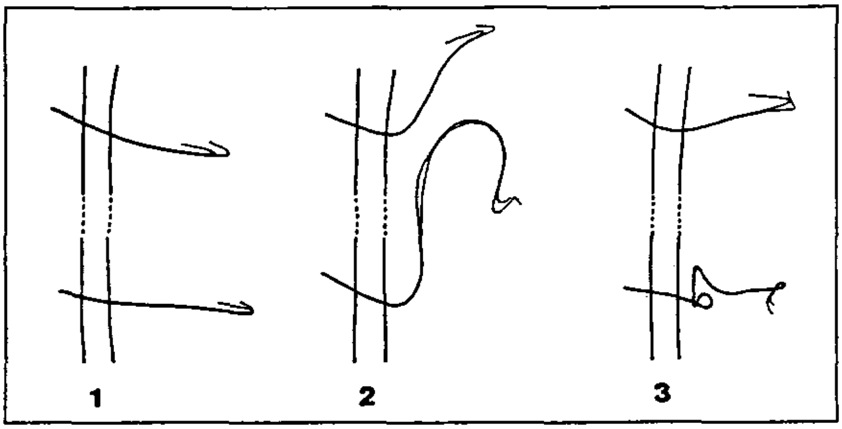

FIGURE C-3

Drawings of fine wires reproduced from radiographs of intramuscular locations. Vertical lines represent the skin contour: 1 = after withdrawal of insertion needle, 2 = during the first muscle contraction. and 3 = relaxed muscle after the 50th contraction.

Reproduced with permission from Jonsson B, Komi PV:Reproducibility problems when using wire electrodes in electromyographic kinesiology. New Developments in EMG and Clinical Neurophysiology 1:540-546, 1973.

In general the fine wire technique for recording EMG is seldom indicated in ergonomics. When necessary, however, the methods allow the study of specific muscles as they participate in a task of interest. Given adequate training, an ergonomist may find these techniques helpful and appropriate.

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GLOSSARY

Motor Unit—An anterior horn cell, its axon and all of the muscle fibers innervated by the axon.

Potential Difference—A measure of force produced between charged objects that moves free electrons. Also called voltage or electromotive force. The unit is the volt.

Interspike Interval (ISI)—The time between two successive repetitions of a motor unit action potential.

Recruitment—The successive activation of the same and additional motor units with increasing strength of voluntary muscle contraction.

Rate Coding—Process of controlling muscular force by regulating the firing rate of motor neurons.

Power Spectrum—The depiction of the power in a signal by assigning the power of each frequency component in the signal and arranging the components as an array.

Signal Power—Signal voltage squared and divided by the source impedance.

Impedance—The opposition to the flow of alternating electrical current measured in ohms.

Common Mode Rejection Ratio—The difference in signal gain divided by the common mode signal gain.

Voltage Gain—The ratio of the output signal level with respect to the input level.

Noise—Electrical potentials produced by electrodes, cables, amplifier or storage media and unrelated to the potentials of biologic origin.

Isolation—To set two circuits apart, usually by introducing a nonconducting barrier between the circuits.

Input Bias Current—Current that flows into the inputs of a nonideal amplifier (input impedance $\neq$ DO) due to leakage current, gate current, transistor bias current, etc.

Modulation—The variation of the amplitude frequency or phase of a carrier or signal as a means of encoding information.

RMS Processor—An electrical circuit assembly designed to compute the mathematical root-mean-square value of an AG signal.

Linear Envelope Detection—An electrical circuit assembly designed to detect the shape of the envelope of an amplitude modulated carrier or signal.

Integration—The operation of computing the area within mathematically defined limits.

Demodulation—The process of extracting the encoded intelligence from a modulated signal.