CHAPTER 3

Recording Techniques

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RECORDING TECHNIQUES

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INTRODUCTION

This chapter will present fundamentals of recording EMG data during activities of interest to the ergonomist or in the setting where ergonomic activities are performed. Each subheading will discuss important factors for applications of surface electromyographic (EMG) techniques relative to ergonomics. Details of fine wire techniques are located in Appendix C.

ELECTRODE SELECTION

A wide variety of electrodes are available for recording muscle action potentials. Although specialized microelectrodes, laser etched electrodes, and diagnostic type needles are available for use, none of these techniques are practical for use of EMG in ergonomics.[5] The two varieties most frequently encountered and of the greatest practicality and applicability are surface and fine wire electrodes. Surface electrodes are of various types, usually comprising a disk composed of silver-silver chloride (Figure 3-1). The size of these circular shaped disks varies from 1 mm to about 5 mm in diameter. Most frequently, these disks are encircled by a teflon or other similar material that also serves as a mechanism to affix the electrode to the skin surface. In some cases, the electrodes have been mounted into a lightweight housing containing instrumentation that will amplify the signal close to the site of the electrode pickup (Figure 3-2). Although it is possible to produce electrodes for recording of EMG data by locating common solder on the end of the wire, this practice should be avoided. In some cases, electromyographers have used suction type electrodes, but this is an uncommon practice. The National Aeronautic and Space Administration has developed a spray-on electrode with a wire incorporated during the drying process, best for long term monitoring. This technology generally is not available nor particularly necessary.

Which type of electrode to be used for surface EMG depends on the purpose of the study of muscle function during performance. Although surface electrodes will provide a more general representation of muscle activity, limitations exist as to their ability to record the performance of small muscles or muscles located more deeply in the body. If information is required on the function of specific or deep musculature then fine wire electrodes should be selected for use. This selection is also recommended if there is interest in studying specific motor unit properties. Otherwise, for temporal, force, or fatigue relationships, surface EMG generally is satisfactory.

Advantages and Disadvantages

All of the available surface electrode techniques have advantages and disadvantages. Although the primary choice of electrode to be used in any collection of EMG information is dependent on the purpose of the study, consideration should also be given to technical feasibility and ease of use.

One advantage of the surface technique is that the electrodes are readily obtainable or made. They also offer the ergonomist many conveniences in terms of relative ease of application and lessened discomfort to the subject. The discomfort factor, however, may be significant in that where less than optimal instrumentation characteristics exist, skin-electrode preparation may create considerable subject discomfort.

Among the disadvantages for surface electrodes are that the electrodes are not selective to a specific area. That is, the pickup area from muscle is rather generalized. Further, they lack any ability of the user to determine the activity from muscles situated at a depth within a given body part. The general rule of thumb, however, is that the smaller the muscle from which the recording is made, the smaller should be the electrodes. It is not surprising, therefore, that electrode sizes down to 2 to 3 mm are used for some of the smaller muscles. An additional disadvantage is that muscle will move under the skin, thereby creating different volumes of muscle tissue from which the electrode is recording. As Basmajian has noted, substantial progress can be made with skin electrodes in such uncomplicated general investigations, but their routine continued use should be avoided.[6] This condemns the exclusive use of surface electrodes in any circumstance where scientific precision is desirable.

An additional disadvantage associated with surface electrodes is the difficulty they present in determining from which muscle the EMG activity is being generated. This leads to the issue of cross talk, which raises questions as to the validity of recordings. How, in fact, can the electromyographer be sure that the recording is from the muscle of interest? Although efforts have been made to quantify and determine the effect of cross talk, there is no established or easy way for surface EMG to

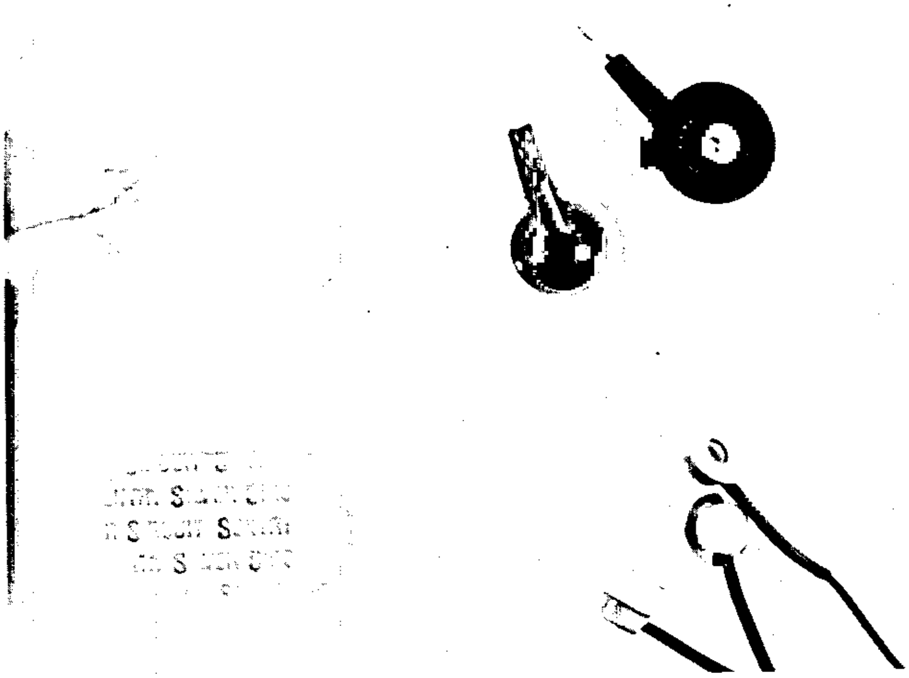

FIGURE 3-1
Standard Beckman surface electrodes (lower right), electrodes with snap on collars and larger diameter pickup area (upper right) and two views of a silver-silver chloride adhesive disk that can be connected to amplifier with a clip lead (left).

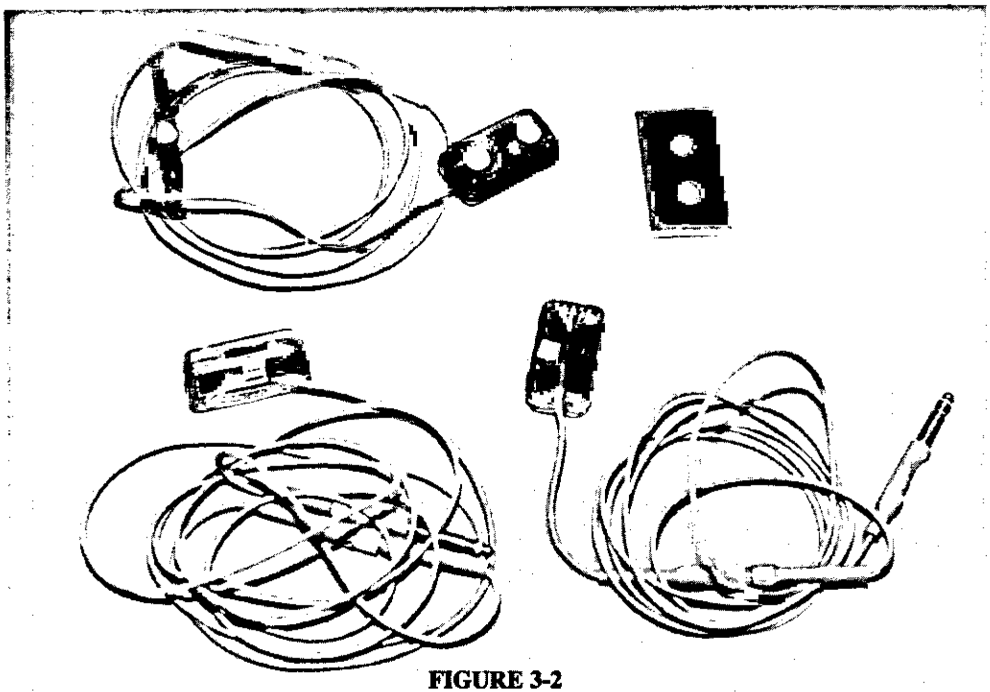

FIGURE 3-2
Three views of a surface electrode with preamplification circuitry included. Dimensions are 33 mm by 17 mm by 10 mm. Double-sided adhesive washer is shown in the upper right.

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eliminate this problem. Some have used functional tests to establish if cross talk occurs between muscles that perform different functions. By using manual resistive techniques for testing isolated motions and observing the display of the EMG signal from all muscles, electromyographers may get assistance in determining whether electrical activity is being recorded simultaneously or by each individual muscle. One specific example may be cited for the gastrocnemius and soleus muscles. Electrodes can be applied over each muscle and the selectivity of the electrode can be demonstrated during knee flexion performed against manual resistance. If the electrodes are applied correctly, such contraction should show high gastrocnemius activity and little, if any, activity from the soleus muscle.

Others have developed and tested models related to cross talk.[6] This work has resulted in the recommendation that calculation of the cross-correlation function be used to determine the presence of cross talk. In most cases, however, the ergonomists using EMG would most probably be interested in generalized activity from a muscle or muscle group, to make inferences about the activity performed. Although cross talk is a factor to consider in using EMG, the practical implications thus may be minimal. A section of Chapter 6 discusses this issue further. Some ergonomists have gone to the selectivity of the fine wire technique to at least help minimize the problem of cross talk.

LOCATION

Despite the relatively long-term use of EMG by investigators in a wide variety of disciplines, little information is available in the literature as to the preferred location of electrode sites. Obviously, for fine wire work the electrode is placed directly in the muscle belly of the muscle of interest. In these cases, similar criteria as used for diagnostic EMG are acceptable (Figure 3-3). For surface electromyography, however, the decision as to where to put the electrode is much less clear. Some have advocated the use of the site where the muscle can be the most easily stimulated (motor point) as where the maximum amplitude of potentials will be located. Basmajian and DeLuca, however, state that this location will not yield the greatest signal amplitude.[7] Rather, they suggest an **interdetection-surface**[4] spacing of 1 cm for surface electrodes.

Some electromyographers have suggested specific anatomic locations for electrode locations (Figure 3-4 A-F).[8] More recently other locations have been specified (Table 3-1, Figure 3-5 A-P).[9] The latter figures, for all but two muscles, include a mechanism to normalize placement based on the body dimensions. This mechanism, therefore, would be an acceptable technique in ergonomic applications.

Among the original investigators of the effect of skin electrode position on EMG potentials were Zuniga et al.[10] They evaluated both unipolar and monopolar recordings and were able to identify locations of greatest EMG output (Figure 3-6). They also evaluated the relationship between the amplitude of the average EMG potential and a longitudinal bipolar electrode position in units of equal distances between the centers of various bipolar electrodes (Figure 3-7). This work on the biceps brachi was followed by the work of Kramer et al, who produced plots of recordings over the muscle midpoint and two other symmetrical positions (Figure 3-8).[11] Other plots are available from the work by Kramer et al, but little additional information is provided. Work has also been completed by Jonsson and Reichmann on multiple-site insertion of fine wire electrodes in back musculature, but no optimal locations were identified.[12] In an attempt to determine the effects of contraction intensity and joint angle, Soderberg et al produced results for hamstring and erector spinae musculature for surface electrodes with a fixed interelectrode distance of 8 mm.[13] A study of Figure 3-9 shows how these variables affect the EMG output.

With consideration given to issues of signal-to-noise ratio, stability (reliability and cross talk), and a presentation of selected data relative to EMG output, Basmajian and DeLuca state that the preferred location of an electrode is in the region of halfway between the center of the innervation zone and the further tendon.[7] More specific guidelines have been provided by Loeb and Gans.[15] They state that the considerations given to the electrophysiological system from which we are recording allows them to make several recommendations regarding electrode dimensions and placement. These include the following:

1. Electrode contacts should lie parallel to the muscle fibers and not across them.
2. Given the duration of the electrical events and the velocity of conduction, the electrode center-to-center separation should be between 2 to 10 mm. Caution is provided that there may be differences in distal versus proximal fibers. Note should also be made that the distances are small because these workers use implanted electrodes in an animal population.
3. Recording contacts should be as large as feasible, meaning that one linear dimension should be at least equal to about half the distance between the pair of electrodes. They caution that **reducing contact dimensions below half the distance between their (electrode) centers adds only to noise and unduly biases the recordings by concentrating on the signals from a few fibers that**

TABLE 3-1

LEAD PLACEMENTS AND FUNCTION CHECKS FOR VARIOUS MUSCLES.[a]

No.	Muscle	Posture	Lead line	Central lead point	Function check	Comments No.[b]
1.	M. epicranius pars frontalis	Looking straight ahead	Horizontal line 3 cm above the eyebrows	Electrode placement: intersections of the lead line and the vertical lines through the pupils	Raising the eyebrows	1, 2, 4, 6, 9
2.	M. sterno-cleido-mastoideus	Head turned slightly toward the opposite side	1. Mastoid process 2. Suprasternal notch	1/3 LLL from the mastoid process	Turning the head to the opposite side	4, 6
3.	M. trapezius pars descendens	Head turned slightly toward the opposite side	1. Acromion 2. Spine of the 7th cervical vertebrae	1/2 LLL	Lifting the shoulder	4, 6, 8
4.	M. deltoideus pars acromialis	Sitting or standing; arm limp	1. Acromion 2. Lateral epicondyle of the humerus	1/4 LLL from the acromion	Raising the arm sideways	4, 6
5.	M. deltoideus pars clavicularis	Sitting or standing; arm limp	Subsidiary line: 1. Acromion 2. Suprasternal notch Lead line: 1. Subsidiary point 2. Lateral epicondyle of the humerus	Subsidiary point: 1/5 SLL from the acromion Central lead point: 1/5 LLL from the subsidiary point	Raising the arm forward	4, 6
6.	M. biceps brachii	Sitting or standing; upper arm vertical; forearm horizontal; palm upward	1. Acromion 2. Tendon of the biceps muscle in the cubital fossa	1/3 LLL from the cubital fossa	Flexing the forearm against an external resistance	4,7
7.	Triceps brachii	Sitting or standing; arm limp	1. Acromion 2. Olecranon	1/3 LLL from the olecranon	Extending the elbow joint	4, 7
8.	M. flexor digitorum superficialis	Sitting; forearm on a table; elbow slightly turned inward; palm upward	1. Medial epicondyle of the humerus 2. Skin fold at the wrist	1/4 LLL from the epicondyle	Flexing the fingers against an external resistance	4, 7, 10, 11
9.	M. extensor digitorum communis	Sitting; upper arm abducted laterally; forearm on a table; palm downward	1. Lateral epicondyle of the humerus 2. Midpoint between the styloid processes of radius and the ulna	1/4 LLL from the olecranon	Extending the elbow joint	4, 7
10.	M. extensor carpi ulnaris	See No. 9	1. Midpoint between the lateral epicondyle of the humerus and the olecranon 2. Styloid process of the ulna	1/3 LLL from midpoint	Abducting the hand sideward toward the ulna	3, 4, 7, 10, 15

TABLE 3-1 (continued)

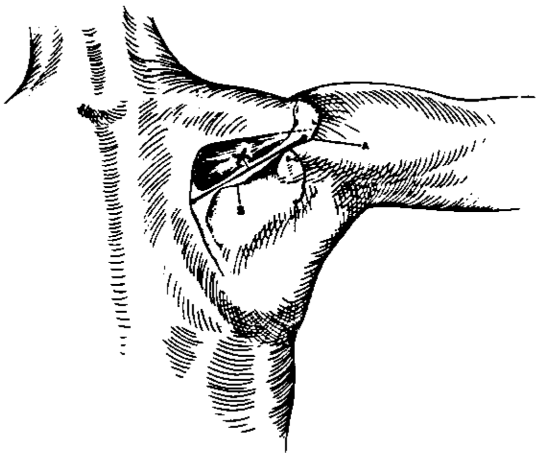
No.	Muscle	Posture	Lead line	Central lead point	Function check	Comments No.[b]
11.	M. pronator quadratus	See No. 8	Parallel line 2.5 cm proximal from the skinfold at the wrist	Point of intersection of the lead line and the tendon of palmaris longus muscle	Pronating the right hand counterclockwise or the left hand clockwise	1, 5, 7, 10,13
12.	M. interosseus dorsalis I	Sitting; forearm on a table; thumb and index finger extended forming a V	1. Vertex of the V 2. Basal joint of the index finger	1/2 LLL	Squeezing the thumb and the index finger together	1, 5, 6
13.	M. erector spinae (trunci)	Standing erect	Parallel line to the spinal column on the crest of the erector muscle	1/6 of the distance from the iliac crest to the spine of the 7th cervical vertebra above the iliac crest	Stooping with a straight back	4, 6, 8, 14
14.	M. vastus medialis	Standing	1. Anterior superior spine of the pelvis 2. Medial gap of the knee joint	1/5 LLL from the knee gap	Extending the knee joint	3, 4, 7
15.	M. tibialis anterior	Standing	1. Lower margin of the patella 2. Lateral ankle	1/3 LLL from the patella	Standing on the heels	3, 4, 7, 15
16.	M. gastrocnemius	Standing	1. Head of the fibula 2. Heel	1/3 LLL from the head of the fibula	Standing on the toes	3, 4, 7

[a] In most instances, the lead line is given in terms of its end point. LLL: lead line length; SLL: subsidiary line length.

[b] Comments:

1. Small electrodes are required.
2. Skin-tinted electrode cases should be used.
3. Shaving may be necessary.
4. Electrode attachment: Adhesive washers.
5. Electrode attachment: Collodion.
6. Electrode attachment should be secured with elastic adhesive tape.
7. Electrode attachment should be secured with circular elastic and adhesive bandages.
8. Interference from the ECG can be reduced by a change of sides or by rotating the lead line about the central lead point.
9. Interference from the EOG and the EEG can be reduced by a high-pass filter with a break point of 20 Hz. Eye blink artifacts can be minimized by slightly shifting one of the electrodes.
10. Crosstalk from other forearm muscles will occur.
11. The signals of the finger flexor muscle are weak since other muscles are superimposed. Different portions of the muscle attached to the different fingers can be selected by shifting the or tion of the lead line either to the thenar or the hypothenar eminence. The final position should be confirmed by palpation while moving the finger under study.
12. Different portions of the muscles belonging to the different fingers can be recorded by shifting the orientation of the lead line either toward the ulnar or the radial styloid. The final positi should be confirmed by palpation while moving the finger under study.
13. The tendon becomes prominent if the palm is strongly cupped. If the tendon is absent, extend the skin fold of the palm (Linea stomachica). The electrodes should not be attached over the tendons.
14. Large stooping movements impose considerable strain on the attachment and may cause failure. A horizontal or oblique orientation of the adhesive tape will reduce the strain. The differe myoelectric activities between the sides may amount to a 3:1 for equal loading (Groeneveld 1976).
15. This body site exhibits very high skin impedance (Almasi and Schmitt 1970).

SUPRASPINATUS



SOLEUS

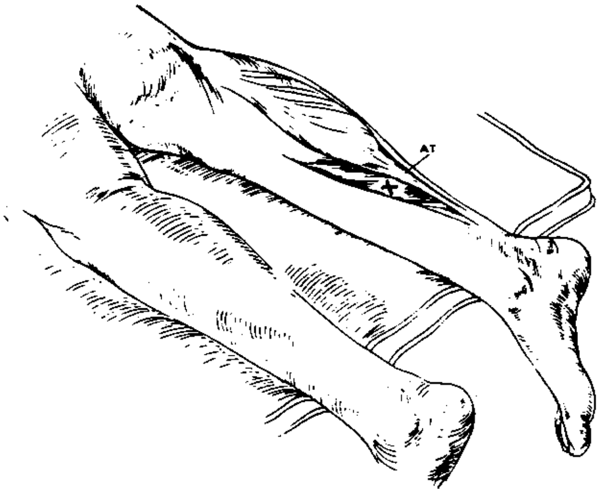


FIGURE 3-3

Examples of suggested needle insertion sites for muscles a) supraspinatus and b) soleus.

Reproduced by permission from DeLagi EF, Perotto A, Iazzetti J, et al: Anatomic Guide for the Electromyographer. Springfield, IL, Charles C. Thomas, Publisher, 1975.

may be lying right on top of one small contact.

4. Bipolar recording contacts should be as similar as possible in size, and impedance.
5. Specific rules apply to the selective recording or rejection of electrical potentials.[15]

In view of the limited availability of information as to optimal electrode positions, electromyographers are required either to locate the best anatomical position or to use the work of previous investigators to justify their electrode locations. That more numerous descriptions for electrode locations do not appear in the scientific or applied literature is surprising.

No matter the electrode location, numerous techniques are available to validate or verify the electrode location. In the case of the fine wire technique, some electromyographers have used stimulation through the implanted wires to determine if the appropriate muscle contracts. The contraction usually is determined on a subjective or clinical basis. Many others have used standardized manual muscle testing procedures to help determine if the muscle of interest is being activated during the given contraction. However, a limitation is that isolation of any given muscle cannot be guaranteed. Because local muscle or nerve blocks are not practical, techniques of validation and verification of the optimal location for surface electrodes are less than scientifically desirable.

THE ELECTRODE AS TRANSDUCER

The chemical electrode transducer is the means by which muscle activity may be detected. A great variety of electrodes are used in EMG but common to all electrodes is a metal-electrolyte interface.[7] The electrode is formed of metal, and the electrolyte may be an electrolytic solution or paste, as used with surface electrodes, or the tissue fluids in contact with the embedded electrode. It is at the site of the electrode-electrolyte interface that an exchange occurs between the ionic current of the various tissue media and the electron current flow of recording instrumentation. The quality of an electrode as a transducing element depends on the ability of the interface to exchange ions for electrons and vice versa, with equal ease, thus preventing the formation of a charge gradient at the electrode-electrolyte interface.

ELECTRICAL PROPERTIES OF THE ELECTRODE-ELECTROLYTE INTERFACE

The ideal characteristics of the nonpolarizable electrode-electrolyte interface are not realized in practical electrode systems. The charge gradient, or "electrode double layer" as it is known, exhibits undesirable electrical properties. Although these properties may be modeled as combinations of resistance, capacitance and a direct current potential, their magnitude is unique to each electrode application. The electrode metal, its area, the electrolyte, the current density, and the frequency of current are all factors that influence the magnitude of the impedance.[16] The frequency dependence of the electrode-electrolyte impedance, decreasing with increasing frequency, attenuates lower frequency components of the detected EMG to a greater extent than higher frequency components. This action is typical of a class of electronic filters termed **high-pass** filters. Although the impedance-frequency transfer characteristic of a particular electrode-electrolyte combination is difficult to predict, the electrode detection surface area is a key variable in determining the magnitude of the electrode impedance. As illustrated in Figure 3-10, an increase in the surface area of an electrode type resulted in a decrease in electrode impedance.

THE BIPOLAR ELECTRODE CONFIGURATION

Electromyographic detection electrodes are used nearly always in a bipolar configuration. In the bipolar electrode configuration, two electrodes are used at the detection site and a third common-mode reference, or **ground** electrode, is placed distally in a neutral electrical environment. This arrangement of electrodes is dictated by the use of a differential preamplifier as the means of signal amplification. The differential preamplifier increases the amplitude of the difference signal between each of the detecting electrodes and the common mode reference. Signals that are common to both detection electrode sites are termed common mode signals and produce a nearly zero preamplifier output. This desirable characteristic of differential preamplifiers significantly improves the signal-to-noise ratio of the measurement and allows the detection of low level EMG potentials in noisy environments. (See Chapter 4 for greater details.)

The sizable benefits of the bipolar electrode configuration are achieved at some cost. An undesirable side-effect to this arrangement is the role the differential amplifier plays as bandpass filter. The filtering action occurs as a result of the differences in the time of arrival of the signal at each detection site. Because the differential amplifier amplifies only the difference in potential at each electrode, a signal frequency whose wavelength is equal to the interelectrode distance or is an integer multiple of that frequency would be cancelled. Figure 3-11 illustrates the bandpass response. Signals whose wavelengths are equal to double the interelectrode distance are passed without attenuation. It should be evident that the larger the electrode spacing, the lower the frequency at which the first null occurs. Consequently, the bandpass filtering effect is of more concern for surface electrodes.

RELIABILITY AND VALIDITY

The complexity of the detected EMG should not be understated. A brief review of the factors known to effect the signal information content is illustrative. These factors are discussed in greater detail in Chapter 4 and listed in Chapter 4, Table 4-1. The detected waveform, thus, is representative of many influencing and often conflicting factors. It should reasonably be considered a limited view of the phenomena, as if one were viewing a distant scene with unfocused binoculars.

Considering the sheer number of factors influencing the information content of the detected EMG, it is prudent to question the reliability of information obtained. Fortunately, many of the factors can be controlled, particularly if surface electrodes are used. The size and type of the electrode, the preparation of the recording site, the interelectrode spacing, and the standardized location of electrodes relative to anatomical landmarks, are all factors that may be controlled to improve the reliability of the measure. Anatomical variation within and between sexes and motivational inconsistency are more difficult to assess and control.

The reliability of each available method is an important factor in investigating muscle function. In general, across channel (muscle) comparisons are precluded because of differences in instrumentation and constituencies of body tissues from one recording area to another. Further, between subject comparisons are precluded on the basis of individual differences and subcutaneous fat, muscle geometry, and other variances. In virtually all instances, therefore, a normalization process should be completed to allow for comparisons. Frequently, both clinicians and researchers have been using the procedure of recording the EMG during a maximum voluntary contraction and then converting the values recorded during the test or procedure to a percentage of the EMG produced during the maximum voluntary contraction. (See Chapter 6 for greater details.) Individual variations that preclude direct comparisons, thus, can be taken into account. In any case, measurements made during one day and one setting are considered to be far superior because they generally will avoid the issues associated with between-day reliability and reproducibility. In those instances when the study procedure or design requires EMG measurements during multiple sessions, however, issues of reliability must be considered. Because the across-day and between-muscle comparisons are limited, for reasons specified in earlier portions of this section, attention should be paid to normalization procedures described in Chapter 6.

Despite the extensive use of EMG for the last several decades, little work has been completed that examines reliability issues. In one of the earliest studies, Lippold

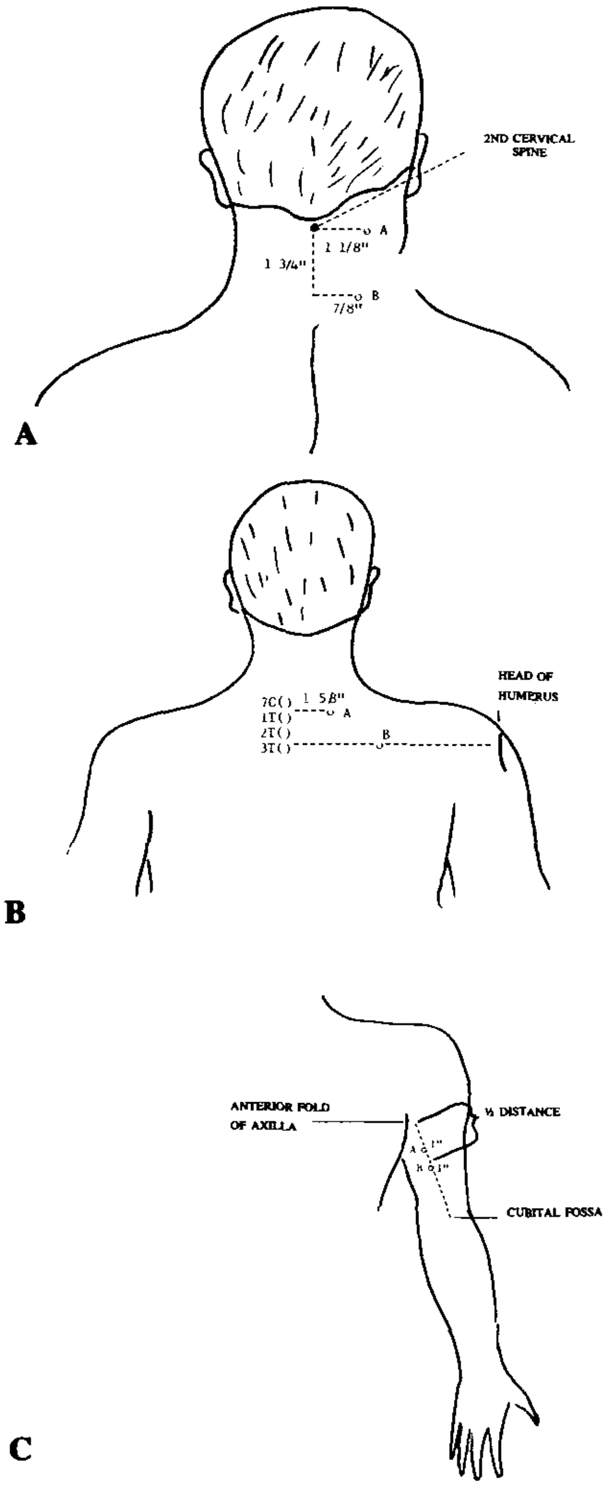


FIGURE 3-4A-F

Recommended locations for surface electrode leads for selected muscles (Davies JF: Manual of Surface Electromyography. WADC Technical Report #59-184, December 1959).

reported interday reliability coefficients for recorded EMG.[17] The values, ranging from .93 to .99, were high, partly because electrodes were not replaced between trials. Viitasalo and Komi, in applying electrodes over the motor point of the rectus femoris muscle, used an integrated signal from which to derive reliability coefficients.[18] For a maximal contraction, values ranged from .80 to .91 between contractions within day, and .64 to .73 between tests within day. Submaximal between-day tests produced coefficients that ranged from .80 to .86.

Reliability has also been studied during functional activities such as gait. In comparing electrode types, Kadaba et al showed that the variance ratio can be used to demonstrate that surface electrode recordings produce higher reliability than those from fine wire electrodes.[19] Yang and Winter evaluated reliabilities from submaximal and maximal contractions for the triceps muscle, testing on three different days.[20] They recorded EMG during 5 maximum voluntary contractions of 1-second duration and 10 submaximal efforts, 5 at each of two different levels. These investigators demonstrated that contractions of 30% and 50% of maximum yielded the highest intraclass correlation coefficients, .78 to .95 respectively, depending on the number of days and trials included in the analysis. Maximal contractions produced coefficients that ranged from .52 to .81. While offering several explanations for the coefficients attained, they comment that the significance of their work is that the maximum voluntary test is not the most reliable method for day-to-day recording.

PREPARATION OF ELECTRODES-SUBJECT INTERFACE

The method of electrode application will depend on the electrode selection and the instrumentation available. The following sections will discuss the application techniques for surface electrodes. The specifics associated with fine wire technique are detailed in Appendix C.

Surface electrodes, as indicated in previous sections of this chapter, vary greatly in size and type. Most will be adhered by a doubled-sided adhesive washer that should first be affixed firmly to the electrode surface. If preamplifiers are available that contain the electrode surface, the same procedure can be followed. The available surface of the recording site should then be filled with an appropriate conduction gel. Excess paste is removed so the conductive gel is flush with the adhesive washer that has been placed on the disk.

Before fixing the electrode to the skin the preparation of the subject needs to be completed. The amount of this preparation will primarily be dependent on the instrumentation available. Onsite preamplification (see

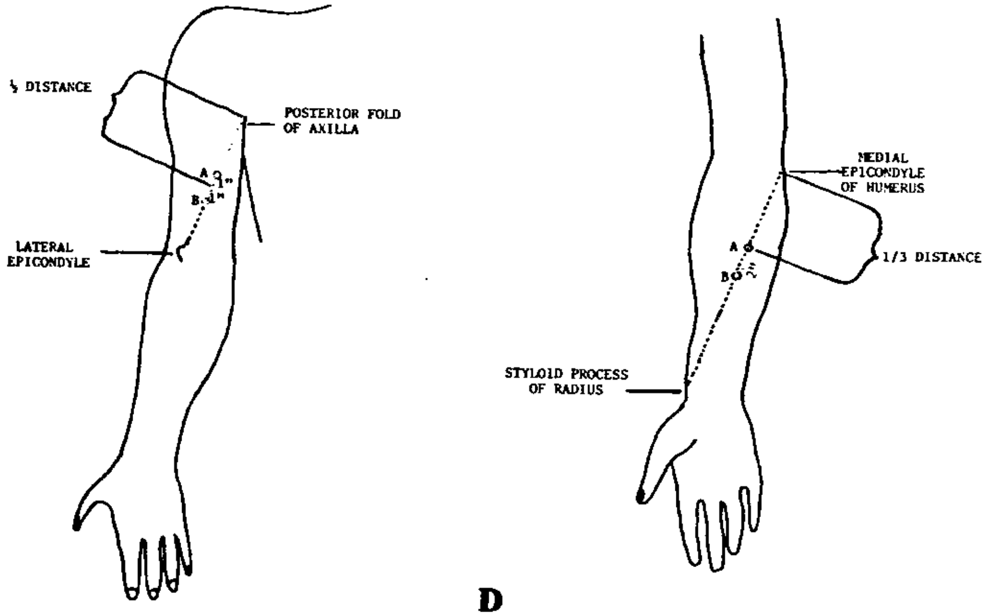


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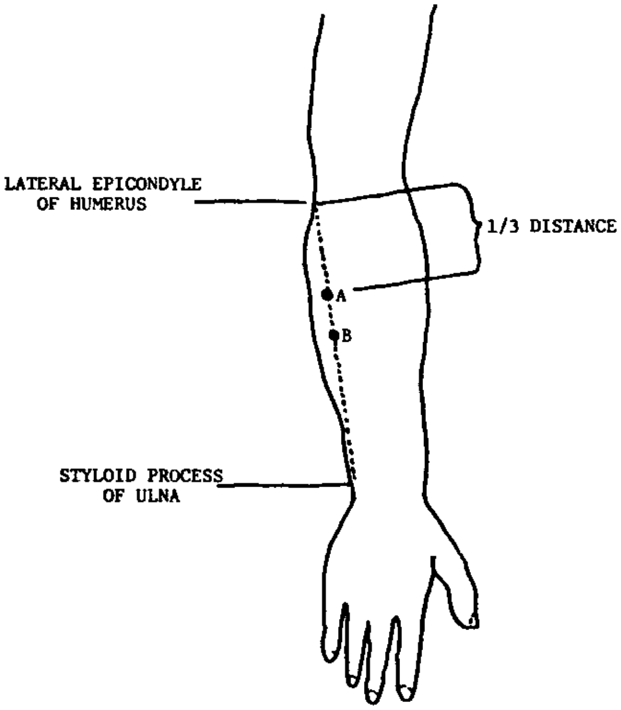
FIGURE 3-4A-F (continued)
Recommended locations for surface electrode leads for selected muscles (Davies JF: Manual of Surface Electromyography. WADC Technical Report #59-184, December 1959).



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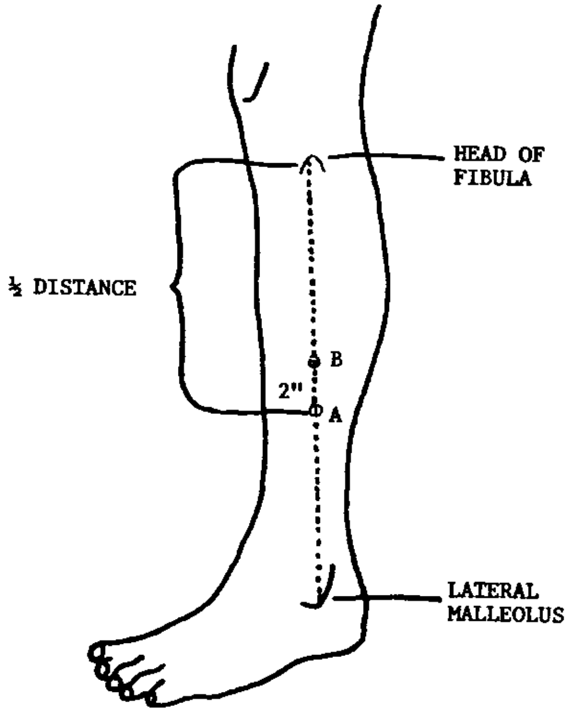

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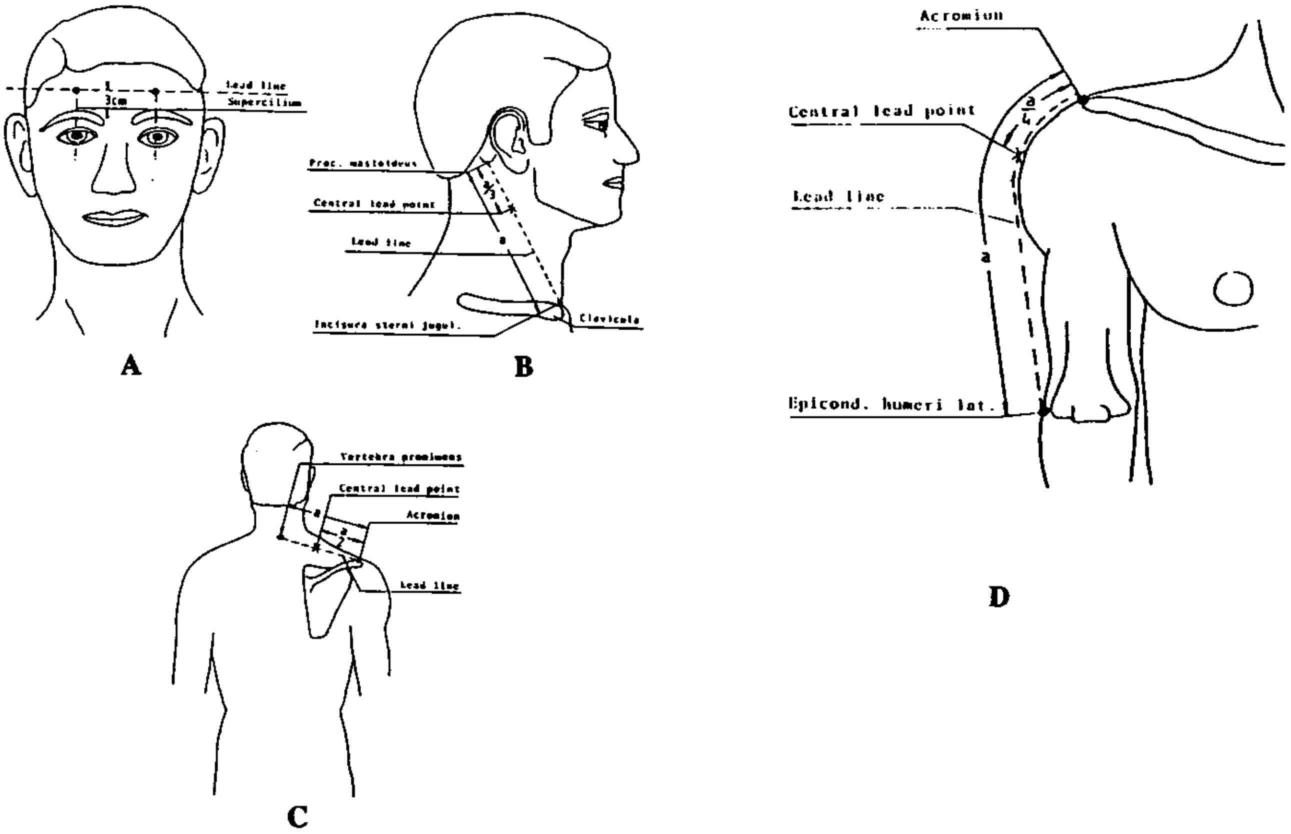

FIGURE 3-5A-P

Recommended locations for surface electrode leads for selected muscles.

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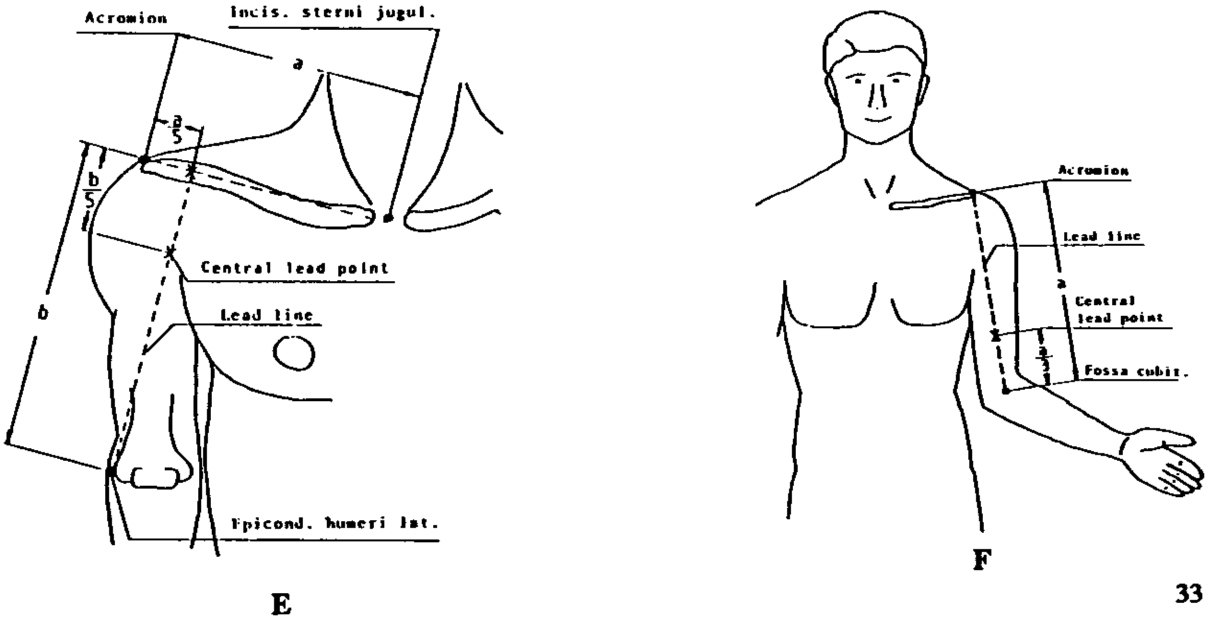

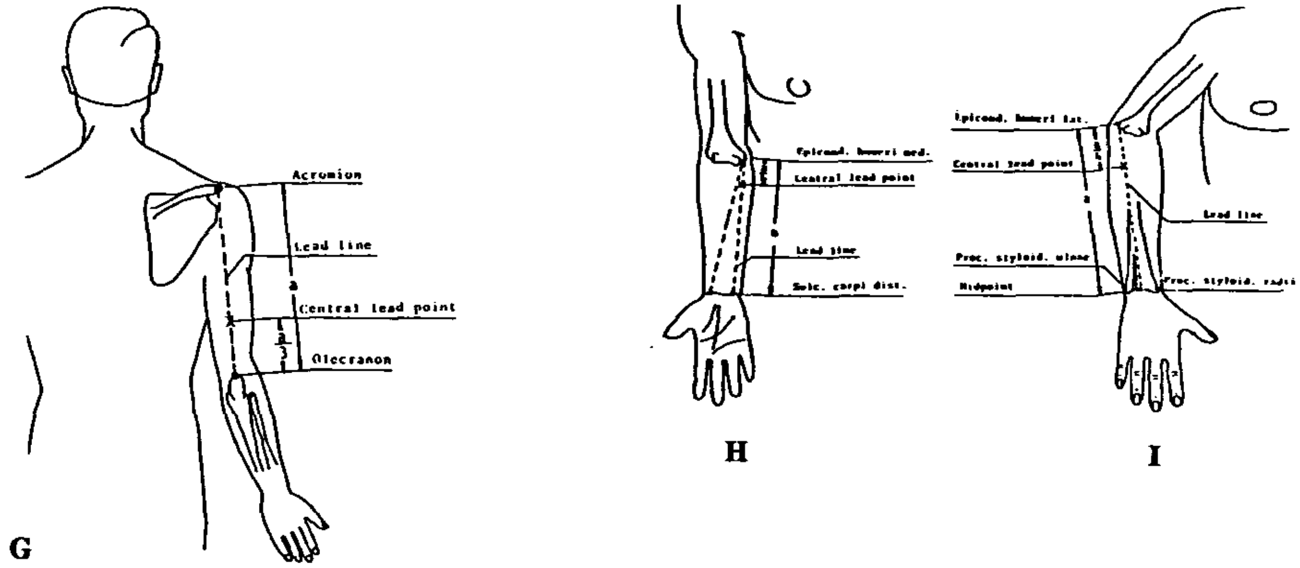

FIGURE 3-5A-P (Continued)
Recommended locations for surface electrode leads for selected muscles.

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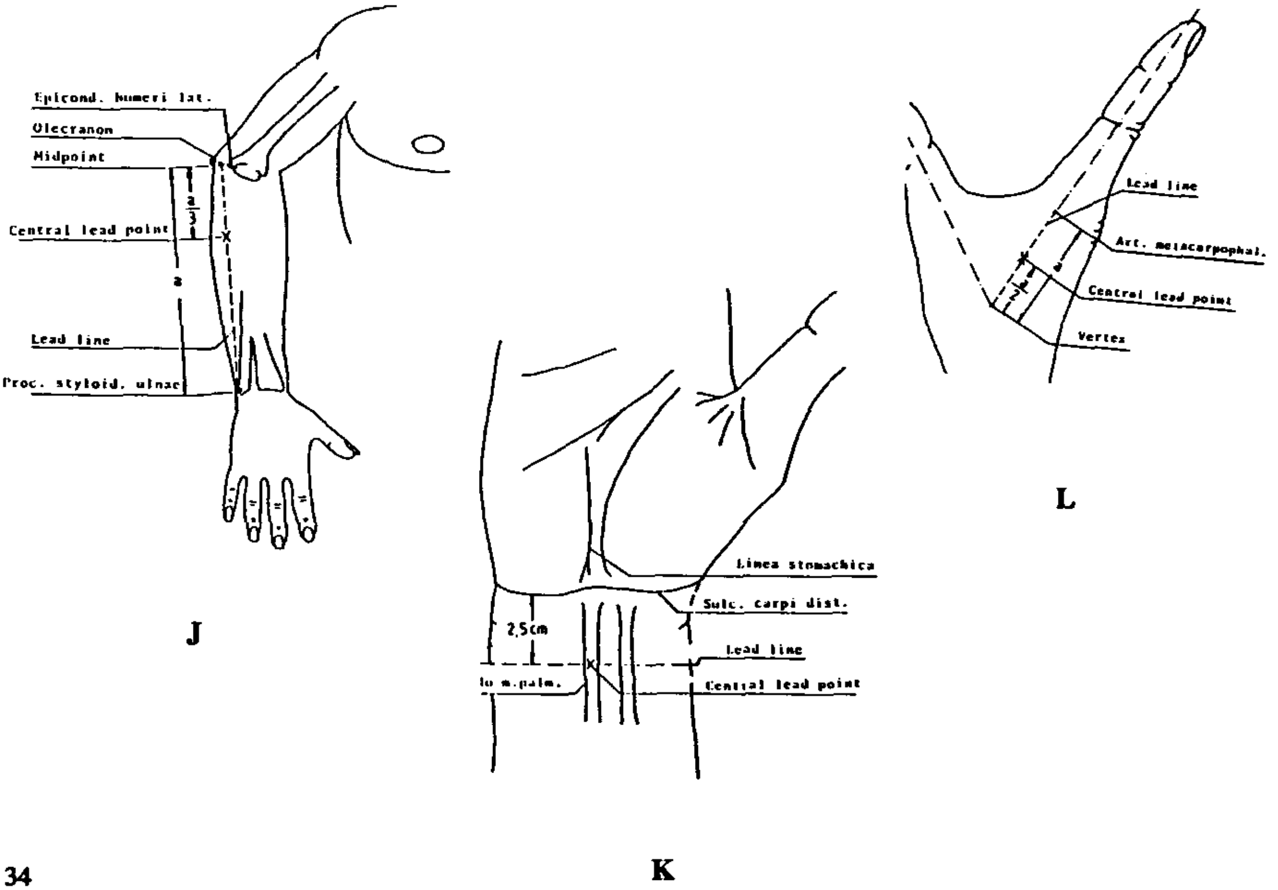

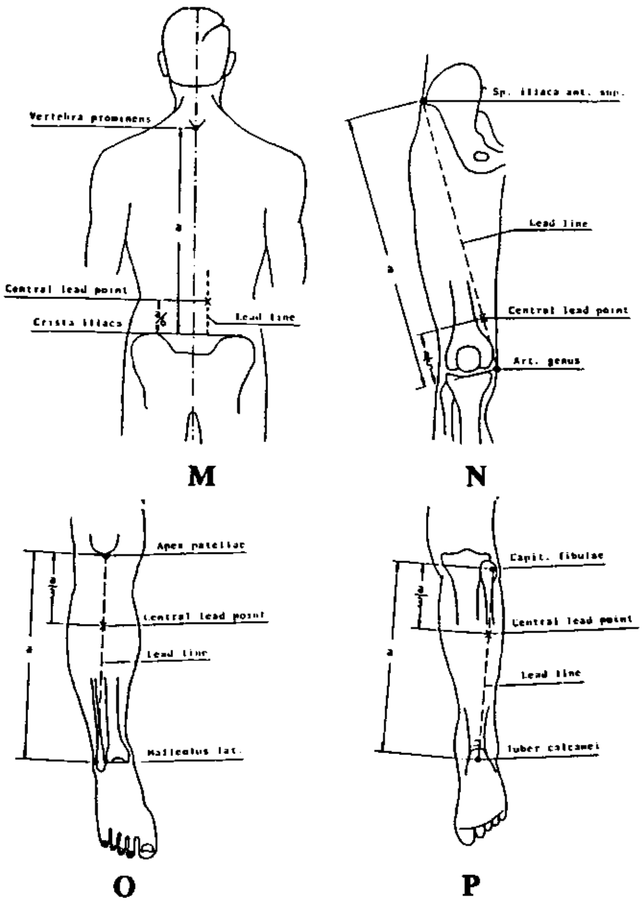

FIGURE 3-5A-P (Continued)
Recommended locations for surface electrode leads for selected muscles.

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Chapter 4) has been noted virtually to eliminate specific skin preparation. In this case, the surface of the skin can be wiped lightly with alcohol to help assure good adherence of the adhesive washer to the body. However, if preamplification is not available and instrumentation of poor characteristics is used, the skin must be abraded at least lightly with an emory cloth. An abrasive conductive gel could also be used. Alcohol on gauze may also be used, but it is generally less effective. In any case, a general recommendation is to lower skin resistance to less than 500 ohms to eliminate artifacts from th ing. Such resistance can be measured simply wit of a hand-held volt-ohm-meter by applying the t from the EMG electrodes to the ohm and common terminals of the meter. Resistance will be read in ohms. Note should be made that the amount of resistance will diminish some as the conductive gel penetrates the surface. In many cases, the electromyographer will find it helpful to wrap lightly either elastic bandages or a substance such as prewrap, used by athletic trainers, over the electrode attachments to prevent movement and loosening during muscular effort or body movement.

Regardless of the electrode technique used for the study of EMG activity, appropriate procedures should be used following data collection. For surface EMG, a cleaning of the subject's skin with alcohol soaked gauze will suffice. Electrode cleaning can be accomplished with gauze soaked with distilled water, before any of the conductive get hardens. If hardening has occurred, more vigorous wiping should accomplish the necessary cleaning . Other solvents or cleaning agents are greatly discouraged because they may have a negative interaction with the materials used in the electrodes.[7]

ARTIFACTS

Several major artifacts occur that must be avoided to have an appropriate and high quality signal. Mechanically induced artifacts are very common and occur when cables are handled or allowed to move when activity occurs. Changes may also be seen with electrode movement occurring between the skin and electrode interface. These artifacts are usually of low frequency. A major problem also can be 60 cycle interference. This occurs when a reference electrode is not applied appropriately on the subject, when there is a loose wire, or when electrical fields persist. The latter can come from improper shielding of wires. If 60 cycle interference (50 cycle in some countries) continues to be a problem in recordings, attention should be paid to the environment, including grounding of all outlets and evaluations of equipment in use in adjacent areas. One other important artifact the electromyographer needs to be aware of is that produced through the electrocardiogram. This is noticeable particularly over the lumbar portion of the erector spinae muscles and in certain other muscles such as the gluteus medius. Figure 3-12 shows the most common artifacts encountered during the collection of EMG data.

To eliminate artifacts, consider certain important factors. Among these are that an optimal electrode design will minimize electrode impedance. In addition, high quality instrumentation is essential– including a differential amplifier with a high common-mode rejection ratio. Further, an adequate reference electrode and the

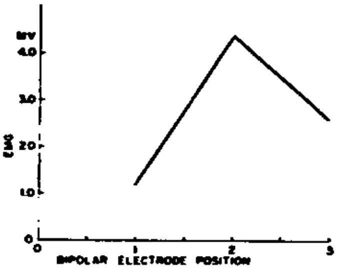


FIGURE 3-6

Relationship between amplitude of averaged EMG potentials and longitudinal bipolar electrode position in units of equal distances between the centers of the various bipolar electrodes.

Reproduced by permission from Zuniga EN, Truong XT, Simons DG: Effects of skin electrode position on averaged electromyographic potentials. Arch Phys Med Rehabil 70:264-272, 1970.

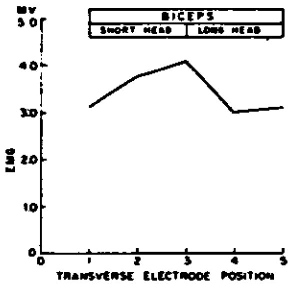


FIGURE 3-7

Same relationship as depicted in Figure 3-6 except for transverse monopolar electrode position.

Reproduced by permission from Zuniga EN, Truong XT, Simons DG: Effects of skin electrode position on averaged electromyographic potentials. Arch Phys Med Rehabil 70:264-272, 1970.

minimization of the number of devices concurrently collecting data help to avoid ground loops. The use of battery driven equipment is also recommended.[15]

Evaluation of the raw signal is essential to assure that there are no artifacts produced. A variety of gain and sweep settings on an oscilloscope is the preferred mode to monitor this signal. This should be done before, during, and after data collection to help assure the electromyographer that data is artifact free.

PHYSIOLOGIC AND HISTOLOGICAL EFFECTS

Ordinary use of EMG has no known adverse physiological effects on the human body. Those systems that do not provide subject protection with shock resistance circuitry or that are powered by conventional wall currents, however, are potentially dangerous. Efforts should be made, therefore, to assure that these factors are taken into account before proceeding with data collection. A discussion of the effect of fine wire electrodes on tissue is presented in Appendix C.

TELEMETERIZED ELECTROMYOGRAPHY

Use of telemeterized EMG has the great attraction of relieving subjects from the constraint associated with the instrumentation necessary to record data. Partly as a result of this interest, systems have been devised to record multichannel EMG data using telemeterized information. Although this method of data recording is inherently appealing, great consideration needs to be given to the design and selection of the telemetry equipment and to the experimental purpose and configuration (see Chapter 4 for further discussion). Although having the subject actually carry the mass of the transmitter and associated instrumentation probably is not difficult for most human subjects, there are equipment difficulties such as in being able to modify the number of channels, the gain of the instrumentation, and the range of transmittal.[15] Each of these factors, therefore, must be taken into account in the design phases of any experiment or data collection procedure.

Loeb and Gans detail the numerous limitations associated with the use of telemetry.[15] They discuss these limitations in terms of range, special orientation, and transmitting traditionally available within the instrumentation. Further difficulties arise in using multichannel techniques even though multiplexing is available. Winter et al, however, have stated that it is possible to multiplex about eight subcarrier channels to carry a modified EMG signal.[21] Other limitations associated with telemetry include the ability to provide adequate control of sensitivity, noise, and cross talk. Newer transmitters now serve the purposes associated with collection of EMG data in the work setting. Note should be made, however, that these techniques have successfully been used in evaluating activities performed at the work site or during functional activities such as locomotion.[22,23] Work experience with seasoned investigators or technicians should be gained before embarking on the use of a telemeterized EMG system.

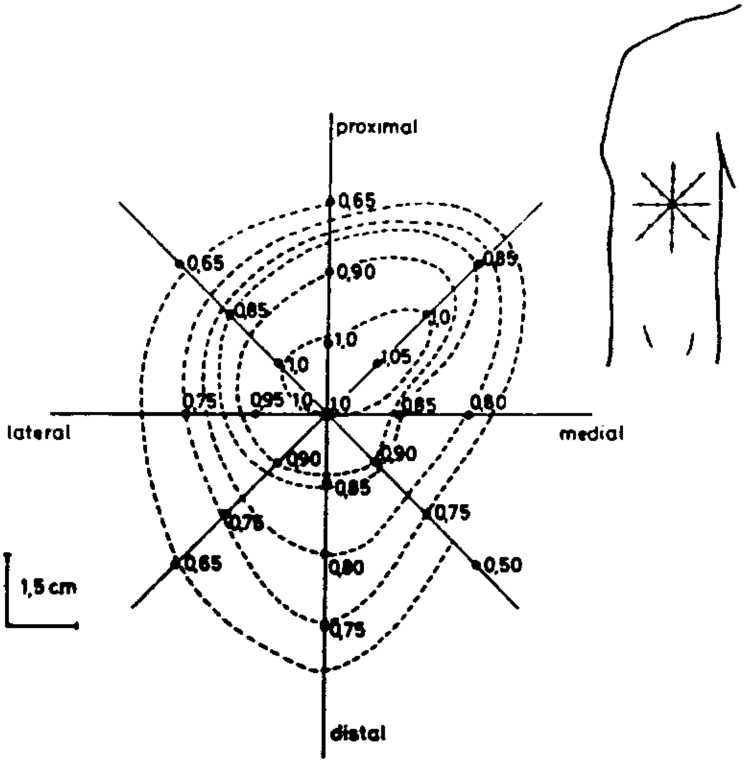
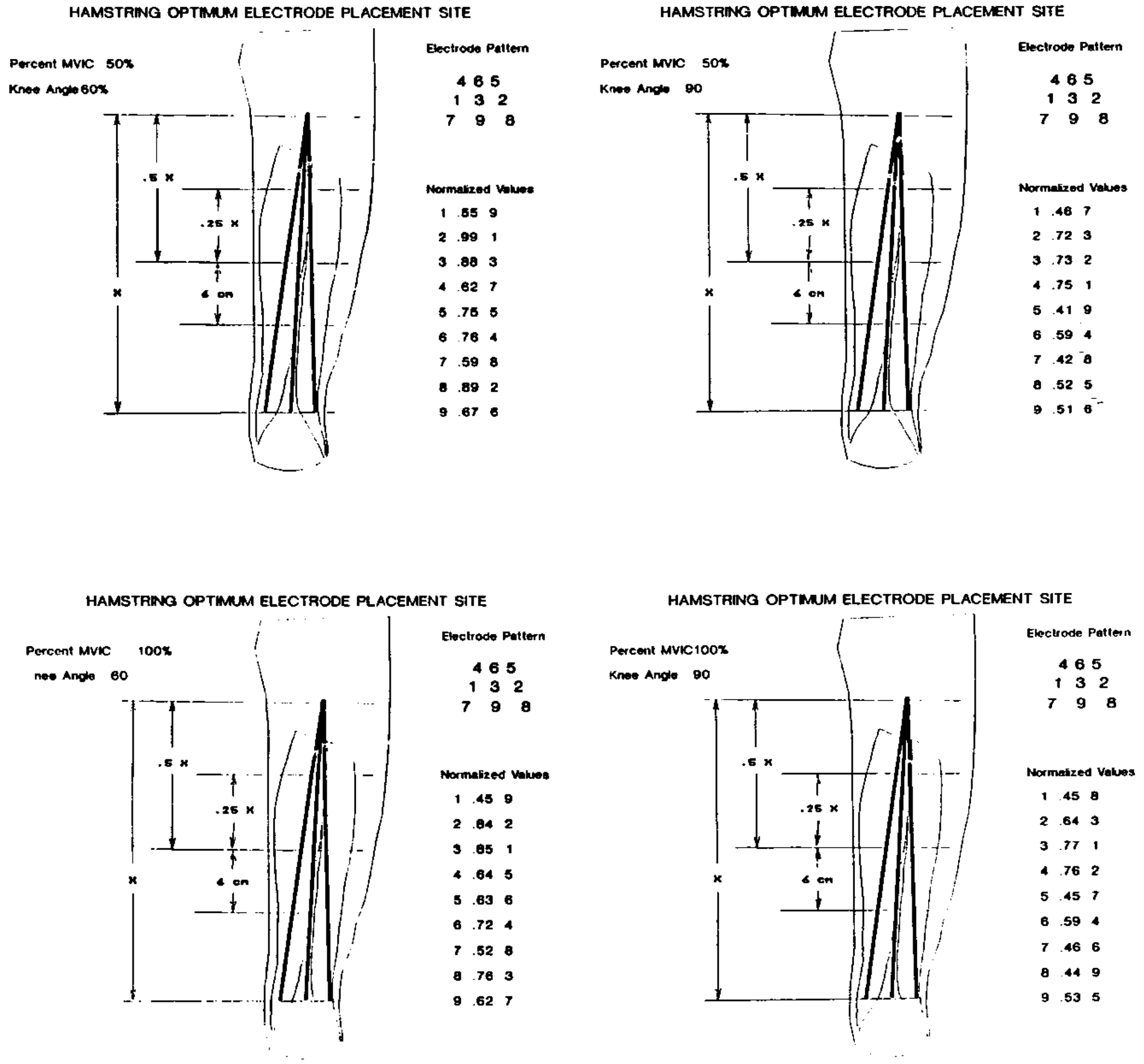


FIGURE 3-8
Influence of electrode placement on the amplitudes of the potentials in the electromyograph. A synchronous three-channel recording from the muscle midpoint (reference point for calculating) and two positions symmetrical to it are the basis of the measured values.

Reproduced by permission from Kramer H, Kuchler G, Brauer D: Investigations of the potential distribution of activated skeletal muscles in man by means of surface electrodes. Electromyogr Clin Neurophysiol 12:19-24, 1972.



HAMSTRING OPTIMUM ELECTRODE PLACEMENT SITE

Percent MVIC 50%
Knee Angle 60%

Electrode Pattern

4 6 5
1 3 2
7 9 8

Normalized Values

1	.55	9
2	.99	1
3	.88	3
4	.62	7
5	.75	5
6	.76	4
7	.59	8
8	.89	2
9	.67	6

HAMSTRING OPTIMUM ELECTRODE PLACEMENT SITE

Percent MVIC 50%
Knee Angle 90

Electrode Pattern

4 6 5
1 3 2
7 9 8

Normalized Values

1	.46	7
2	.72	3
3	.73	2
4	.75	1
5	.41	9
6	.59	4
7	.42	8
8	.52	5
9	.51	6

HAMSTRING OPTIMUM ELECTRODE PLACEMENT SITE

Percent MVIC 100%
nee Angle 60

Electrode Pattern

4 6 5
1 3 2
7 9 8

Normalized Values

1	.45	9
2	.84	2
3	.85	1
4	.64	5
5	.63	6
6	.72	4
7	.52	8
8	.76	3
9	.62	7

HAMSTRING OPTIMUM ELECTRODE PLACEMENT SITE

Percent MVIC100%
Knee Angle 90

Electrode Pattern

4 6 5
1 3 2
7 9 8

Normalized Values

1	.45	8
2	.64	3
3	.77	1
4	.76	2
5	.45	7
6	.59	4
7	.46	6
8	.44	9
9	.53	5

FIGURE 3-9

Electrode location sites for hamstring muscles under varying conditions of knee angle and percentage of maximum voluntary contraction (MVC). Normalized values are to MVC as reference contraction for each pre-amplifier electrode location and then rank ordered to identify where maximum voltage was obtained.

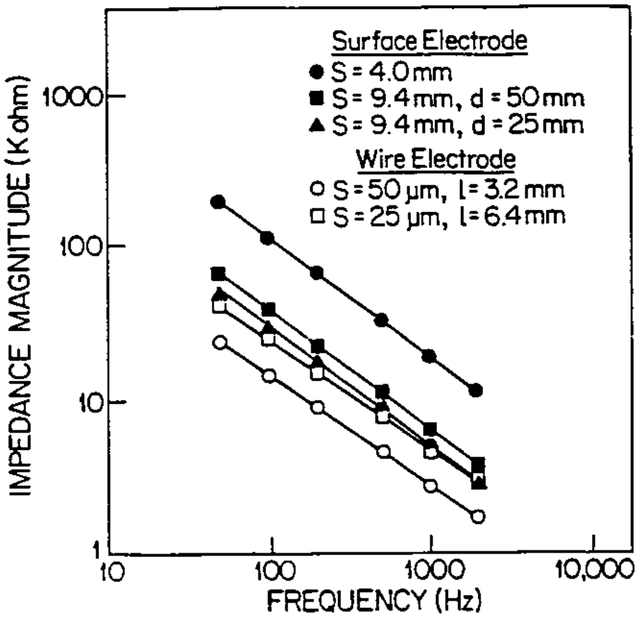


FIGURE 3-10

Typical values of the magnitude of the impedance of surface and wire electrodes. The filled circle represents a monopolar arrangement; the rest are all bipolar. S, diameter of detection surface; D, interdetection surface spacing; L, exposed tip length.

Reprinted with permission from Antonelli D, et al: Pathokinesiology Laboratory, Rancho Los Amigos Hospital, CA, 1982.

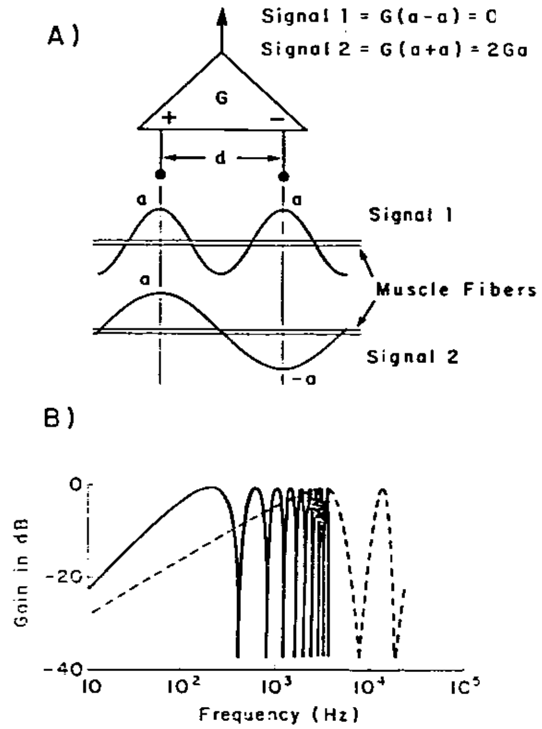


FIGURE 3-11

Schematic (A) of the filtering aspects of the differentially amplified bipolar detection. As the signal travels along a muscle fiber at its conduction velocity, it will pass by both detection surfaces sequentially, with a delay proportional to the interdetection surface spacing (d). Some of the frequency components of the signal will have wavelengths which are multiples of the distance d (cancellation frequency); these will cancel out when amplified differentially. When the wavelength is equal to 2d (as in signal 2), the signal will pass. (B) Alternating behavior of the filter function and cancellation frequencies. The solid line represents the filter function of a surface electrode and is calculated for an interdetection surface spacing of 1 cm and a conduction velocity of 4 m/s. The dashed line represents the filter function of a typical needle electrode and is calculated for an interdetection surface spacing of 0.5 mm and a conduction velocity of 4 m/s. It is apparent that the bipolar filter function is of concern for surface electrodes and has minor relevance in needle electrodes.

Reprinted with permission from Basmajian JV, DeLuca CJ: Muscles Alive: Their Functions Revealed by Electromyography, ed 5. Williams & Wilkins, 1985, Figure 2.16, p 49.

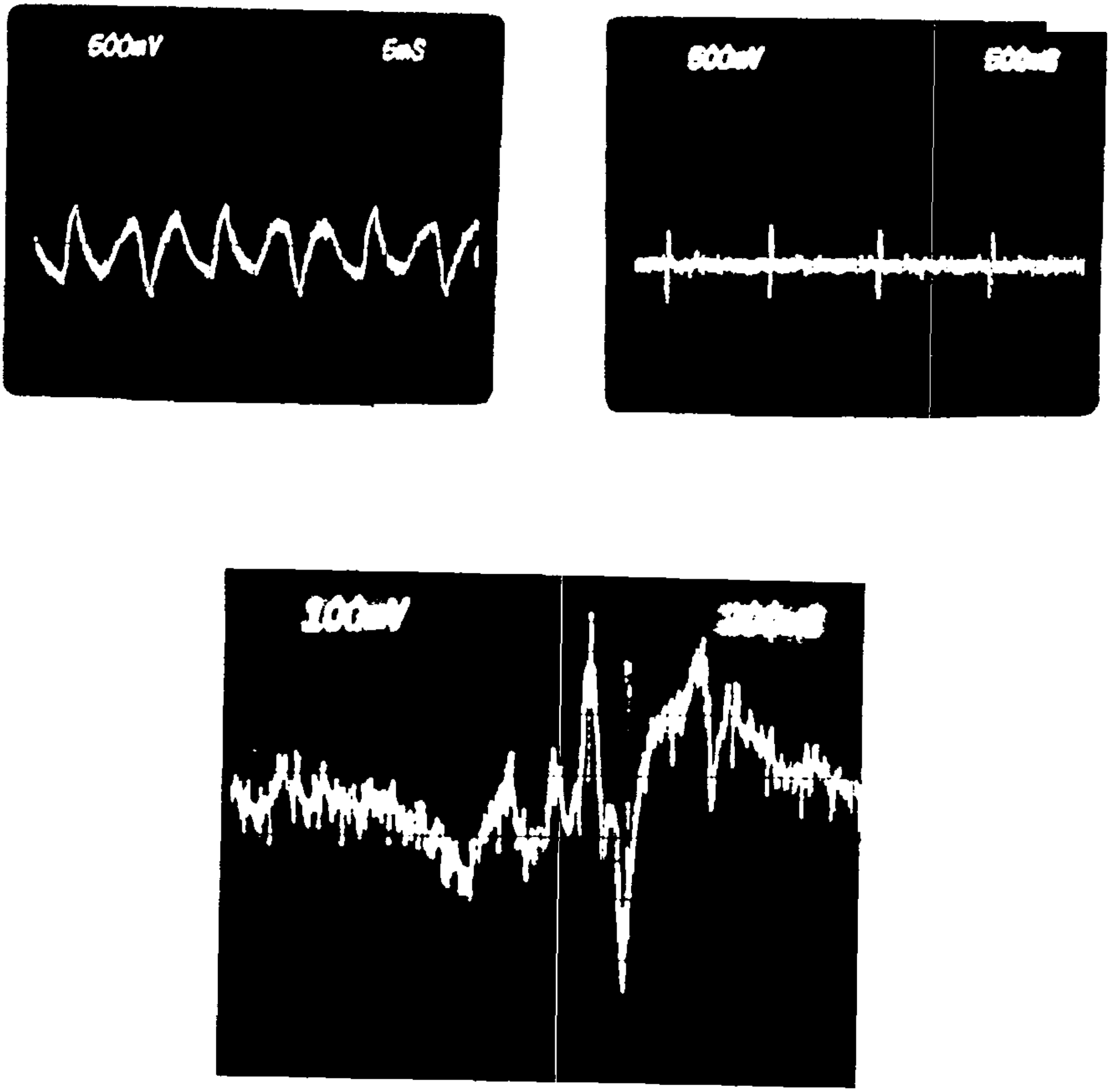


FIGURE 3-12
Common artifacts encountered during EMG recordings: a = 60 Hz; b = electrode or cable movement; c = EKG.

SUMMARY

This chapter discussed the techniques of surface EMG as applicable to ergonomics. Reasons for electrode choice and location are specified, and the technique of application is stated. Although limitations associated with data of these types are noted in this chapter, the ergonomist should be able to use EMG in a valid and reliable manner.

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