INSTRUCTION MANUAL

Model 1089 MK III
Checktrode®

July 2008

UFI serving science with experience

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WARRANTY

All UFI instruments are warranted against defects in materials and workmanship to the original using purchaser for a period of one year from the date of original purchase. The warranty is void if our inspection shows the equipment has been tampered with, or installed at variance with factory designated procedures or has been subjected to negligence, misuse, accident beyond normal usage, or has had it's serial number altered, defaced, or removed.

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NO person, including any dealer or agent is authorized to assume any liability for UFI. When corresponding or communicating with UFI concerning your equipment, please include the model number and serial number of the instrument.

UFI instruments and transducers are subject to continuous improvement. We reserve the right to modify any design or specification without notice and without incurring any obligation.

ALL UFI TRANSDUCERS AND ELECTRODES ARE COVERED BY OUR EXCLUSIVE "LIFELINE® WARRANTY" AS OUTLINED BELOW

LIFELINE® WARRANTY

If your UFI transducer, electrode, or electrode tester ceases to operate---regardless of the cause---accidental, intentional, or whatever---**RETURN IT TO US.**
We will repair it or replace it with a new one for a minimal handling charge, as listed below:

Model 1010, 1010C, 1020, 1020EC, 1020FC, 1110	$25.00
Model 1030, 1040, 1070, 1081FT	$50.00
Model 1081 & 1081 SNP	$11.00
Model 1089 MK II & MK III	$65.00
Model 1130, 1131, 1132	$35.00

Prices subject to change

MODEL 1089 MK III
CHECKTRODE®
(eff. 6/99)

INTRODUCTION

The CHECKTRODE® Electrode Tester may be used to:

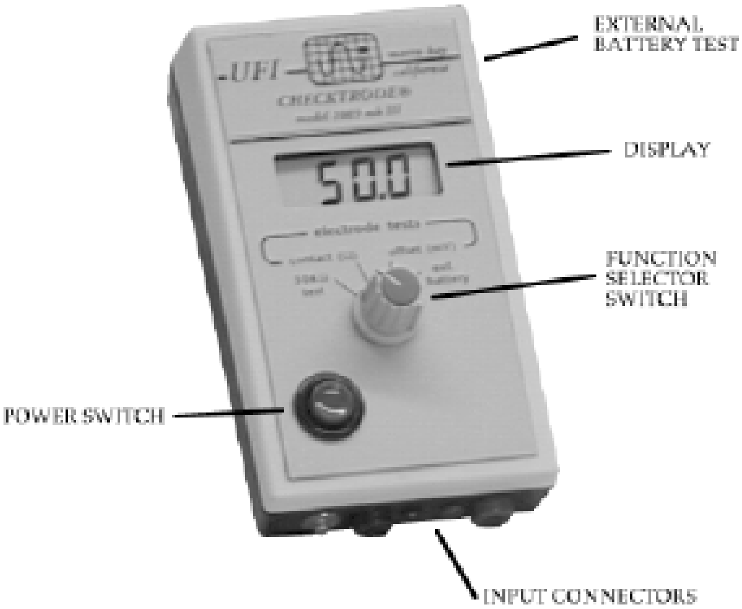
A. Test the integrity of electrode/skin contact in physiological and/or bio-electrical data acquisition systems;

B. Test the integrity of associated electrode wires used in such systems;

C. Test the "quality" of the electrodes;

D. Test external batteries (9 V & others) such as used in telemetry and other physiological monitoring systems.

1. FUNCTION OF CONTROLS AND CONNECTORS



POWER SWITCH

Push button — turns unit ON.
Power remains ON for approximately 3 minutes,
then **AUTOMATICALLY TURNS OFF.**

FUNCTION SELECTOR SWITCH

4 position switch which selects the measurement function of the CHECKTRODE®

(a) 50 KΩ TEST

Connects a precision 50 KΩ resistor to the CHECKTRODE® INPUT. The instrument should read between 49.5 and 50.5.

(b) IMPEDANCE (KΩ)

Displays the electrode contact impedance in (between 0 and 199.9 KΩ). The display will indicate "1" when the electrode impedance exceeds 199.9 KΩ.

(c) OFFSET (mV)

Displays the potential generated by a pair of electrodes when connected to the body. Known as "offset potential", this measurement indicates the purity of the metals used in the electrode manufacturing process. The lower the reading the higher the purity. Readings which vary wildly or which exceed "10" are usually indicative of severe electrode problems.

(d) EXT BATTERY

Reads the voltage of a battery when it is connected to the EXTERNAL BATTERY TEST CONNECTOR.

NOTE: THE BATTERY IS READ USING A 1,000Ω LOAD!

2. USING THE CHECKTRODE®

CHECKING INTEGRITY OF ELECTRODE CONTACT

(a) Prepare the electrode sites and attach the electrodes.
NOTE: See attached discussion "Instrumenting the Subject"

(b) Connect the electrodes to be tested to the input jacks.

(c) Depress the POWER SWITCH.
Set the FUNCTION SWITCH to 50KΩ TEST
The display should indicate between 49.5 and 50.5.

(d) Set FUNCTION SWITCH to CONTACT (KΩ) —

The display will indicate the integrity of the electrode contact. Higher impedances are indicative of poor skin preparation, and often result in a recording with moderate to severe motion artifacts.

5KΩ or below	Good prep
5KΩ — 10 KΩ	OK, but can cause some noise
10 KΩ — 30KΩ	FAIR, might improve with time, but for best results, should be removed and skin re-prepped.
30 KΩ & above	BAD, will cause much noise on the recording with the slightest patient motion. REMOVE AND RE-PREP!

CHECKING INTEGRITY OF ELECTRODE WIRES

(a) Connect one electrode wire to the RED ELECTRODE INPUT JACK.

(b) Energize instrument as above. Select "CONTACT KΩ"

(c) Connect the free end of the wire to the snap connector on the CHECKTRODE. The display should read "00.0" and not change. If the display changes with wire motion, there probably is an intermittent open in the wire.

CHECKING OFFSET POTENTAL

(a) Connect electrodes as in Section 1.

(b) Select "OFFSET" with the FUNCTION SWITCH

(c) The display will indicate the potential generated by the half-cell combination of two electrodes and the body. The reading should be "10" or below.

BATTERY TEST

(a) Select "EXT. BATTERY" with the FUNCTION SWITCH

(b) Depress POWER button

(c) Connect the battery to be tested to the BATTERY TEST CONNECTOR. The display will indicate the battery voltage.

Technical aspects of monitoring the heart rate of active persons[1]

H. M. Hanish, R. A. Neustein, C. C. Van Cott and R. T. Sanders

See pages 1160, 1161, and 1162

Other papers in this symposium are concerned with the value of heart rate as a reliable index of work. This paper is concerned with techniques to obtain interference-free data to facilitate accurate heart-rate counts from active persons.

Methods

Proper techniques, good materials, and an understanding of instrumentation are necessary to obtain reliable heart-rate measurements from extremely active subjects. An evaluation of this data acquisition task leads to the conclusion that the techniques and materials that follow are most conducive to good, clean data: *1*) the EKG should be used rather than pulse; *2*) sense EKG with small Ag/AgCl electrodes held on by adhesive disks (this minimizes inertial and relative motion problems); *3*) place electrodes over bone rather than muscle to minimize electromyogram (EMG) artifact; *4*) abrade electrode sites for good contact to eliminate external interference; *5*) test electrode impedance to verify good contact; and *6*) use a neutral, nonirritating, long-term electrode gel.

Of the above, the most dramatic results in terms of signal improvement are realized from proper skin abrasion.

Discussion

Both pulse and EKG are widely used in research laboratories to obtain the heart rate. The pulse is a low magnitude mechanical phenomenon that must be converted into an electric signal by a transducer. It is possible to obtain the rate mechanically from the pulse, but the motions associated with even slight activity produce enough aberrant signals to obscure pulse signal. A low mass, uniaxially sensitive transducer is usually applied to areas of maximum pulsatile action and minimum muscular activity, typically the finger tip, or radial notch. Even at these locations, however, activities involving the use of the hands or arms can readily produce enough motion between the subject and the transducer to develop signals many times that of the pulse (Fig. 1). For this reason, pulse pressure is not considered a reliable source of a signal that can be used for counting the heart rate of active persons.

The EKG is the dominant bioelectric signal throughout much of the body and can be reliably obtained from the chest wall even during extreme thoracic activity (Fig. 2). The amplitude of the EKG signal is low in absolute magnitude, varies among subjects, and varies with electrode location on any particular subject. Amplitude in a particular location may change with changes in posture that shift the electrical axis of the heart.

The EKG is basically a low frequency signal with a high frequency component of large amplitude, the R wave or QRS complex. This type of signal is amenable to electronic filtering, particularly if the peak of the complex can be maximized with respect to the rest of the EKG signal. This can be accomplished through judicious placement of the electrodes, guided by a recent EKG of the subject or the readings of an R-wave meter. The effect of variation in electrode position on the amplitude and form of the signal is shown in Fig. 3. It can be seen from the figure that electrode location can be chosen to emphasize the portion of the EKG wave form pertinent to heart-rate counting.

The EKG is accompanied by other bioelectric signals, notably the electromyogram (EMG), as seen in Fig. 2b. Every muscle gives off action potentials when it does work. These signals can be of greater amplitude than the EKG. As shown in Fig. 4, EMG's generally reach their maximum strength at frequencies in the upper portion of the EKG

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[1] From the Special Projects Research and Investigation Group, Biocom, Inc., Culver City, California.

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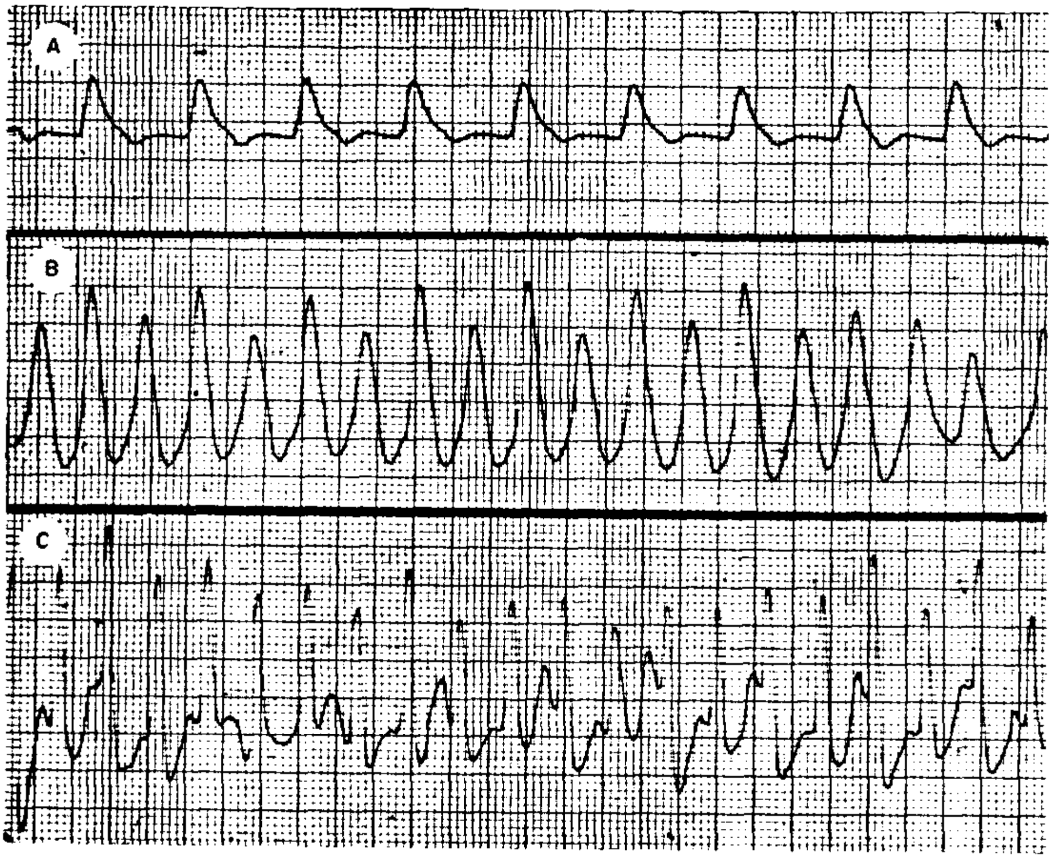

FIG. 1. The effect of activity upon measurement of the finger pressure pulse. Measured with Biocom Mode 1010S pulse transducer on finger tip.
A) Subject at rest; B) subject running in place; C) subject waving arms.

spectrum (1). The quantity of EMG that the electrodes will sense is initially minimized by reducing the amount of muscle mass intervening between the electrodes. The sternum and ribs offer low muscle mass electrode sites close to the heart, where the R wave is generally of maximal amplitude. Electronic filtering can then be used to further eliminate the remaining interferences.

Although it has been shown that the portion of EKG signal pertinent to rate counting can be maximized with respect to interference from bioelectric signals, the absolute value of this signal is quite small. This 1 to 3 mv signal must pass through skin. The electrical resistance of the skin in adults is commonly found to be in the range of 5×10^3 to 5×10^5 ohms (2) and can be as high as 1×10^6 ohms for some subjects. A subject whose skin exhibits these resistance levels between electrodes acts as an antenna for the electrical fields of his environment. The most common of these fields are 50/60 cycle from electrical wiring and electrostatics generated by a variety of sources. These fields can induce, in the EKG circuit, voltages much larger than that of the EKG.

The resulting signal is filled with interference and is unusable. A number of techniques are widely used in an attempt to reduce the skin's resistance, among them alcohol or acetone scrubs, "roughing up" the electrode site with a tongue depressor, and even scratching with fingernails. The results of these methods vary widely and are, at best, unrepeatable.

The skin resistance must be below 5,000 ohms for reliable, interference-free data (3).

FIG. 2. Comparison of EKG of a subject at rest and performing isometric exercises involving thoracic muscles. Measured with Biocom Model 368 EKG telemetry system. Unfiltered. Electrode location: manubrium to rib in V5 position.

A) Subject at rest; B) EKG with EMG for exercise. Note readability of R wave.

These levels are readily achievable with abrasion techniques that remove the epithelium, which is the primary source of the electrical resistance of the skin. Empirical results indicate that the best material for this technique is No. 7447 Scotchbrite scouring pad (a Minnesota Mining & Manufacturing Co. product). Several light swipes across the skin will generally suffice.

The results of abrasion are compared with those of other techniques in Fig. 5. The high resistance of unprepared skin and skin scrubbed with alcohol is reflected in the broad base line. This is 60-cycle interference. The exercise EKG's for these techniques are filled with electrostatic interference, generated by the action of the subject's shoes on the floor. The tongue depressor technique reduces the resistance to a level where 60 cycle ceases to appear, but not to the point where the base line is stable enough for reliable rate counting during exercise. The repetitive disturbance of the base line is attributed to the subject's shoes making and breaking contact with the floor, again producing electrostatic interference. After abrasion, the resistance was low enough to prevent interference. The subject was running in place at the same speed during each test.

The importance of abrasion to repeatedly reliable data cannot be overstressed. If no other consideration in this paper but abrasion is used, the quality of the data obtained will be overwhelmingly enhanced. The subject must be rubbed the right way. The basic technique is: *1*) select electrode sites to emphasize QRS complex and minimize T wave and EMG; *2*) degrease electrode sites with alcohol, et cetera; *3*) abrade each site briskly five or six times to remove the epithelium; *4*) apply electrodes; *5*) check electrode resistance (typically less than 3,000 ohms); and *6*) abrade again if resistance is over 5,000 ohms.

The testing of the electrode/patient resistance is mandatory, because this is the controlling factor in obtaining a stable signal. Detection and correction of high resistance electrodes minimizes reruns of tests and the ensuing feelings of frustration. Persons abrading subjects quickly determine how much abrasion is needed through testing their own technique. The resistance test involves passing an electrical current from electrode to electrode through the subject. This current must be well below 100 μA to avoid the risk of stimulating cardiac problems (4). Common resistance testing devices,

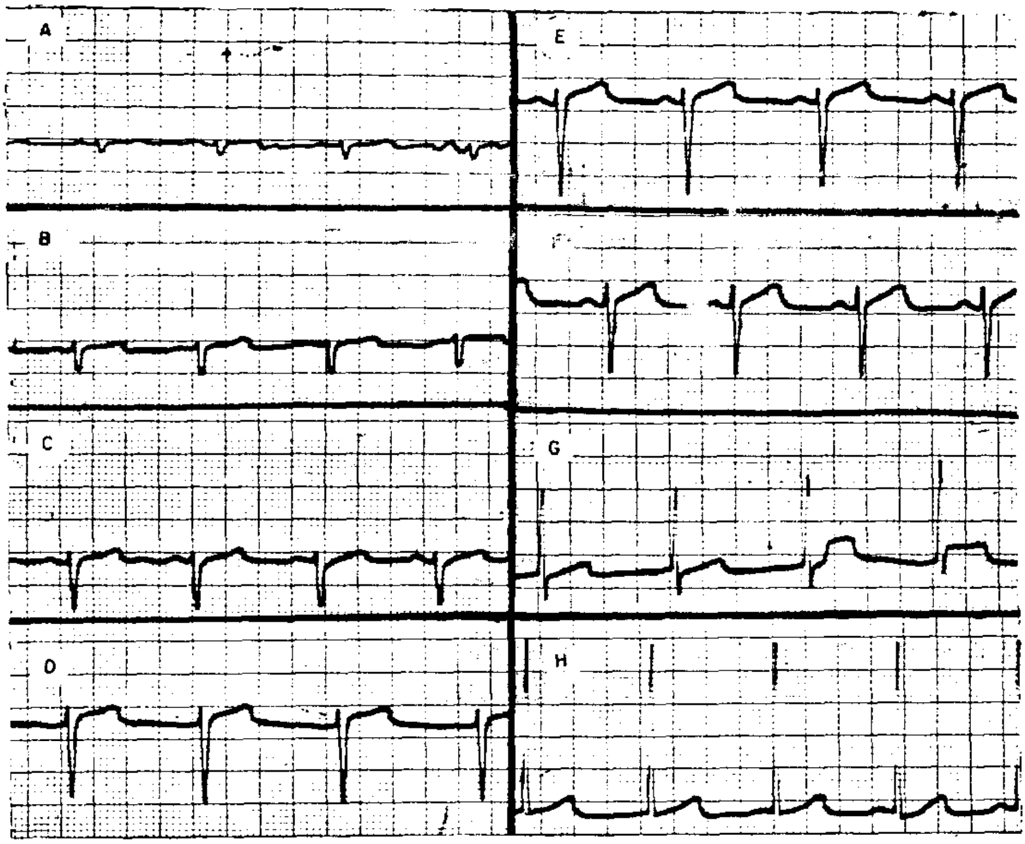

Fig. 3. The effect of electrode location upon the emphasis of pertinent portions of the EKG. Electrode location: manubrium to sites noted. EKG taken with Biocom Model 1083 EX three electrode exercise cable and Biocom Model 2122 bioamplifier.

A) Sternum at 3rd rib; B) sternum at 3rd IC space; C) sternum at 4th rib; D) sternum at 5th rib; E) xiphoid process; F) V2 one rib below; G) V3 one IC space below; H) V4.

such as ohmmeters, produce currents much above this level and, because they test with a relatively fixed voltage, the test current increases as the resistance is reduced. Specialized equipment is available for testing electrode resistance, using limited, constant currents in the range of 25 to 40 μA. This range of currents is well below the threshold of cardiac problem stimulation. Equipment exhibiting these levels of test current should be used.

Abrasion produces low impedance by removing the skin's protective insulating layer. Because of this, the risks of irritation and infection must be minimized through careful selection of the electrodes, the electrode contact medium, and the method of electrode attachment to the subject.

Selection of these items is mediated by their interaction with the skin. The problem here is that the patient/instrument junction involves dissimilar substances; on the side of the instrument, metallic conductors; and for the skin, metabolizing organic tissue with significant aqueous and electrolytic components. If the metal conductor is simply laid adjacent to the tissue, an interaction of the two in the form of ionic polarization may take place, or a chemical reaction between the metal and the electrolyte may occur. Electrical conduction through this junction is made possible by migration of the ions in th ectrolyte to their respective poles. can result in an increase in apparent r ance (or a decrease in voltage) acros electrode junction as the products of trolysis accumulate on the electrodes (ba effects).

The conventional method of attacking these problems is to devise a nonpolarizing electrode, an asymptotically approached goal. Minimum polarization is usually achieved by using a junction of a metal with one of its salts, which then makes an electrolytic junction with the skin and its saline solution. The most common metals and salts for this purpose are zinc/zinc sulfate, mercury/mercury sulfate, and silver/silver chloride. The first two contain ions injurious to tissue and therefore silver/silver chloride is generally used (5).

Electrodes may be placed directly on the skin (dry electrodes) or coupled to it through a column of electrode gel (wet electrodes). As the skin moves under a dry electrode, the contact resistance may vary widely, and, with it, the signal. This problem is usually attacked by increasing the input impedance of the amplifier (a technique used to combat problems of all electrodes). The increase in input impedance reduces that proportion of total circuit resistance contributed by electrode contact. As the amplifier impedance goes up the effects of changing electrode resistance are accordingly reduced, but only with a commensurate increase in susceptibility to interference from external sources (6).

This region of problems may be skirted when electrode contact is made through a captive column of electrode gel to the abraded electrode site. The liquid coupling permits some relative motion between the electrode and the skin with little change in contact resistance. The captive column maintains a fixed contact area, both on the electrode and the skin.

The electrodes should be held in a fixed position, relative to the skin, to eliminate electrode motion problems. This means attachment to soft, flexible tissue, which is metabolizing, sweating, and sloughing off and which may exhibit allergenic reactions. There are two commonly used principles of attachment, compression and adhesion. Compression techniques, typified by clamps and elastic straps, do permit electrode motion on the skin, particularly during activity, because there is no fixed point to which it is tethered. This motion causes shifts in the base line of the EKG data and, therefore, unusable data.

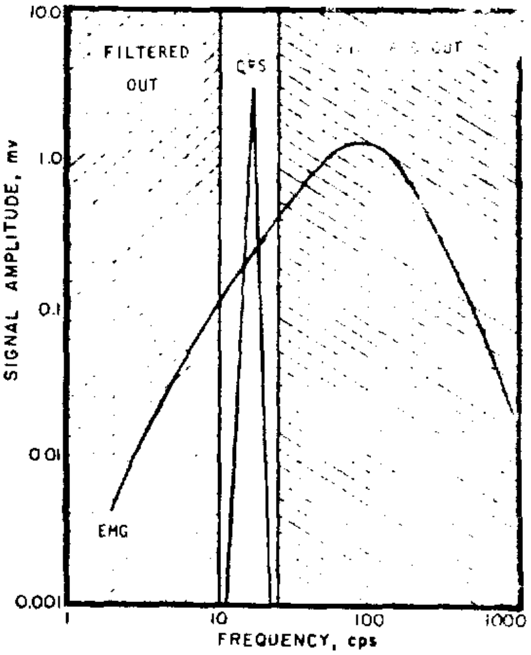

FIG. 4. Comparison of amplitude versus frequency for the QRS complex and a typical EMG signal, showing the regions to be filtered for minimization of residual EMG. EMG from biceps lifting 2.1 kg (2).

Adhesion firmly affixes the electrode in one place. Usually, adhesive tape or a double-sided adhesive annulus (between the electrode and the skin) is used. Careful consideration must be given to the adhesive medium to avoid the chance of irritation. Tapes, such as Johnson & Johnson's Dermicel or Scotch Micropore exhibit hypoallergenic characteristics. Caution should be exercised even with these not to pull or wrinkle the skin, particularly during long-term monitoring. Tape, like rupper straps, may lift off the skin causing base-line shifts in the data. Again, these problems are most evident during activity and may not be discernible when the subject is at rest.

Double sided adhesive annuli (disks) are readily available with hypoallergenic adhe-

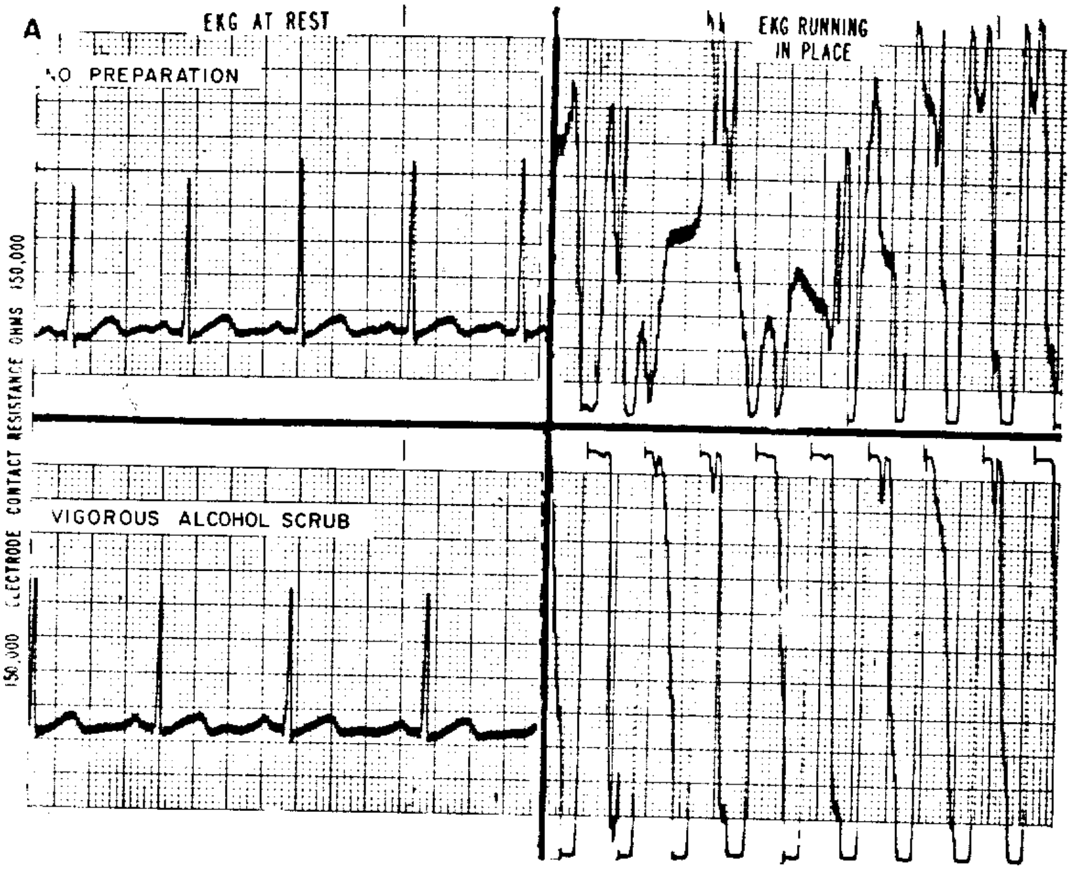

FIG. 5 A and B. Comparison of electrode resistance and EKG for various techniques of electrode site preparation. Electrode location: manubrium to V5. Reference electrode location: V5R. Note PVC in bottom trace. EKG taken with Biocom Model 1083EX three electrode exercise cable. Biocom Model 1090 Biogel biopotential contact medium, and Biocom Model 2122 bioamplifier. Electrode-subject contact resistance measured with Biocom Model 1089 biotest electrode tester. Test current 25 μA.

sives. Such disks are routinely left on for periods up to 4 or 5 days in clinical situations with patients whose skin remains dry and relatively free of oil. Where active subjects are expected to sweat, tincture of benzoin or antiperspirants may be used to prolong adhesive contact. However, the actual site of active electrical contact must not be covered with these preparations or the quality of electrode/patient junction will be degraded.

Electrodes must be small in size and weight to minimize inertia effects. This further reduces any relative motion betewen the electrodes and the skin and any associated artifactual data. The wires of the electrode cable must be durable, yet very flexible, for both subject comfort and minimum injection of "wire noise" into the system. Wire noise does not stem from the relative stiffness of the cable. It is a function of the materials and techniques used to manufacture it. Any wire will generate signals of its own merely by being subjected to accelerative stresses. Special, low-noise cable has been developed that markedly reduces this problem. Unfortunately, this wire is expensive and stiffer than is desirable for EKG electrode applications. Once again, the higher the circuit impedances the greater the system susceptibility is to noise. If the subject contact resistance is kept very low, then the interference from even very noisy wire will be tolerable. This is shown in Fig. 6.

The contact medium, or electrode gel,

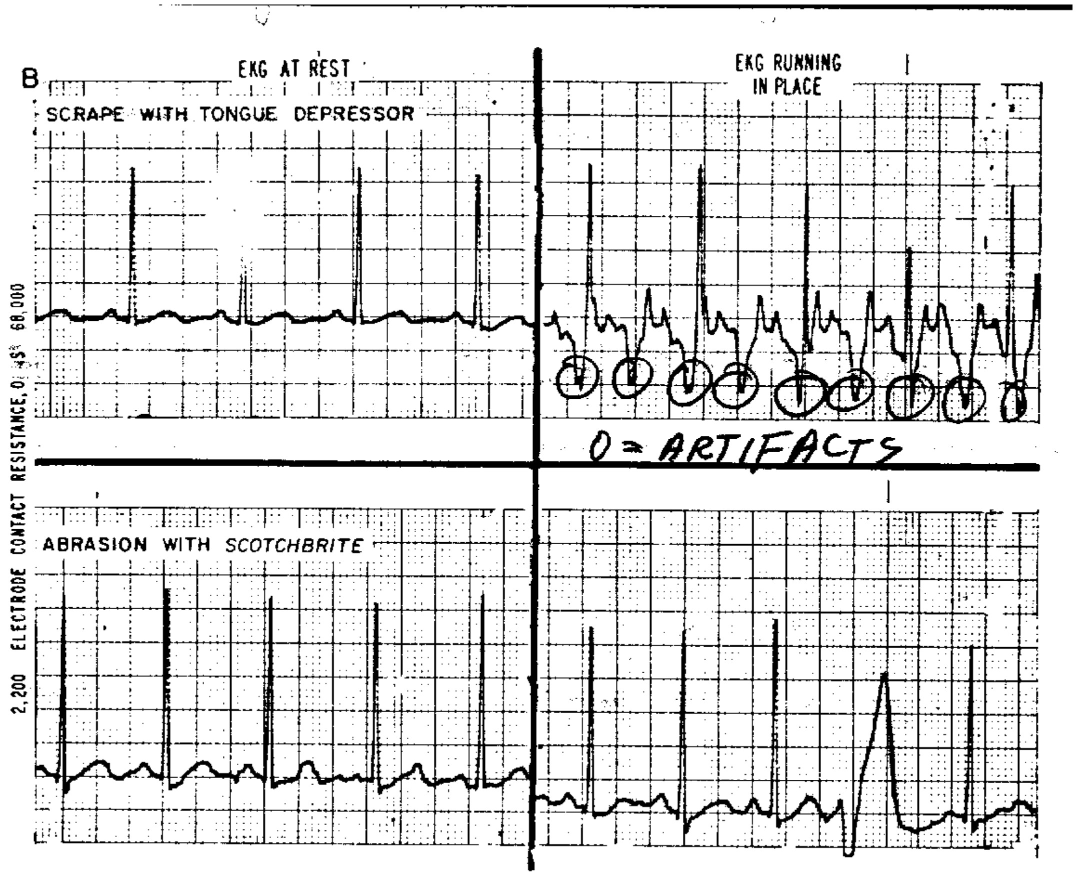

FIG. 5B.

must be carefully selected when abrasion is used. Many of the jellies designed for EKG use in the doctor's office will prove to be highly irritating in long-term application to the body. Lanolin base creams or "sols" have a high resistance and do not work well for application to active subjects. They are too greasy and tend to melt and be absorbed into the skin, thus degrading performance over long periods of time (3). The gel must be nonirritating, preferably pH 7.0, and preserved with bacteriostatic and fungistatic agents. The clarity of the gel is also important, as a clear gel facilitates the detection of voids and bubbles in the filled electrode cavity. These bubbles can move around within the cavity, changing shape and electrode resistance when the subject is active. This is yet another cause of base-line shifts and motion artifacts.

The advent of moderate cost treadmills of good quality has increased interest in monitoring the EKG of active subjects. This interest has brought to light the most discouraging and elusive cause of noise and artifacts, electrostatic interference. This source is present (although reduced) on other than very dry days. It is elusive because it only shows when the subject is moving, and it appears to be very similar to motion artifacts caused by poor or sporadic electrode contact. It is especially apparent on most treadmills, because these machines are essentially Van de Graf generators, among the very first mechanisms used to develop very high energy discharges of static electricity.

Even the electrostatic potentials produced by a treadmill will not affect the EKG when proper techniques are used. This is shown in Fig. 7 for a subject running at 10 mph on a treadmill. The Ag-AgCl electrodes were located on the manubrium and xiphoid process

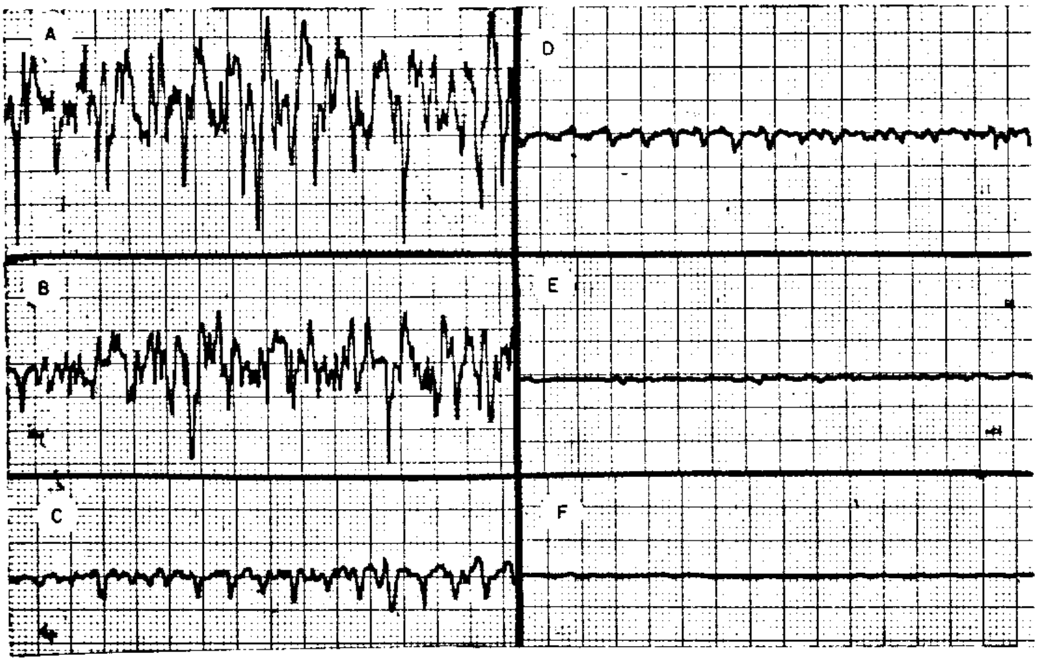

FIG. 6. The effect of electrode resistance upon the magnitude of wire noise produced by vigorous motion of the electrode cable. 1mv/cm. Measured with Biocom Model 2122 bioamplifier, input impedance = 2 megohms, connected to resistance substitution box by shielded single conductor electrode cable.
Resistance = (in ohms) A) 100,000; B) 50,000; C) 15,000; D) 10,000; E) 5,000; F) 2,000.

FIG. 7. EKG from an extremely active subject. Measured with Biocom Model 334A EKG telemetry system. Subject running at 10 mph on treadmill (5% grade). Electrode location: manubrium to xiphoid process.

to minimize EMG and to emphasize the negative going S wave of the EKG. The possibility of false counts of the T wave is minimized in this manner, because the polarity of the T wave is opposite that of the S wave. The liquid junction electrodes were adhesively attached to abraded sites with disks. The electrode/subject resistance was tested and verified to be low with a low level constant current device. The resulting EKG is clearly conducive to accurate heart rate measurement.

Summary

The techniques and materials discussed in this article produce consistently reliable EKG signals from the most active persons. These signals are stable enough to be used with any measuring device that processes EKG to obtain heart rate. The accuracy of heart-rate data from active persons need not be limited by the stability of the EKG. It can be as accurate as the counting method itself.

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