TECHNICAL NOTE

DISTURBANCE-FREE SKIN ELECTRODES FOR PERSONS DURING EXERCISE*

1. INTRODUCTION

In electro-physiological research, frequent use is made of surface electrodes. The surface electrode to be described below has been developed for long-term registration of electro-cardiograms from persons during exercise. The electrode is also suitable for electromyography, electro-encephalography and other purposes. A nearly disturbance-free registration of the signal is obtained, which, in general, facilitates interpretation. Three types of disturbance may occur.

1.1. Electro-physiological category

These disturbances are caused by muscle action potentials, originating from contracting muscles under the area where the electrodes have been placed. By choosing special positions for the electrodes one can obtain minimum disturbance when the subject uses his muscles during exercise. The form of the electro-cardiogram depends on the position of the electrodes (Fig. 1). It is presumed that no special form of the electro-cardiogram is needed.

1.2. Electrical and electromagnetic category

These disturbances can be diminished or cancelled by:
(a) screening the electrode leads; (b) using a differential amplifier; and (c) achieving a low electrode impedance.

1.3. Electro-chemical category

When the electro-cardiogram is recorded from athletes or persons doing physical work, disturbances are often caused by movement of the surface electrodes with respect to the skin or the underlying tissue. We distinguish two interfaces between which disturbances can be caused: that between the metal and electrode jelly and that between jelly and skin. The way to minimize particularly these disturbances will be described below.

2. REQUIREMENTS

Our requirements for the electrodes in this investigation, in respect of the electrochemical category of disturbances, are the following:
(a) few or no motion artefacts should occur in the electro-cardiogram during intensive labour by the subject;
(b) it should be possible to record continuously for at least 12 hr;
(c) the surface electrodes should be watertight in such a way that over the surface of the skin, no short-circuiting is caused by heavy perspiration, or when the subject is under water;
(d) the method of applying the electrode should be as simple as possible.

3. TYPES OF SURFACE ELECTRODES

3.1. The direct contact electrode

3.1.1. Plate electrode. Metal plate held against the skin by a rubber strap. Motion artefacts are caused by insufficient fixation (Fig. 2a).

3.1.2. Metallized gauze-electrode. Metallized nylon fixed with adhesive tape, after Bellet et al. (1961). Motion artefacts caused by too great a flexibility. (Fig. 2b).

3.2. The fluid electrode

3.2.1. Flexible cup-electrode. A plate, gauze or thread is fixed in a rubber housing that is glued to the skin (Rowley et al., 1961). The housing proves to be too flexible (Fig. 2c).

3.2.2. Newly developed rigid cup-electrode. Silver plate fastened in a rigid housing. A linen gauze is attached to the housing that is glued to the skin after jelly has been put into the cup under the gauze (Figs. 2d & 5). This latter type meets the requirements. Measured results are described in § 4.

4. MEASUREMENTS

To investigate the effect of moving the electrodes on the recorded potential differences between the electrodes (see requirement (a) § 2), a circuit diagram representing the electrode system has been designed (Fig. 3a). X, N and Y are the electrodes where the connection with a differential amplifier is made during, e.g., ECG recording. The index N means “no scrubbing”, see below.

\[ E_{1x}, E_{1n}, E_{1y} \] are e.m.f.'s generated in the interface between metal and electrode jelly.

\[ E_{2x}, E_{2n}, E_{2y} \] are diffusion potentials between electrode jelly and skin.

\[ Z_{1x}, Z_{1n}, Z_{1y} \] are transitional impedances between metal and electrode jelly.

\[ R_{ex}, R_{en}, R_{ey} \] are electrode jelly resistances.

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FIG. 2. The same standard exercises as in Fig. 1. Second trace: someone is tapping on the electrodes with his fists. (a) ECG record with plate-electrodes; (b) ECG record with metallized cup-electrodes; (c) ECG record with flexible cup-electrodes; (d) ECG record with rigid cup-electrodes.