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An Analysis of Different Biopotential Electrodes Used for Electromyography

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Measuring electromyographic signals from human body using electrodes is becoming a challenging task nowadays due to its materials used, noise, temperature coefficient, pain and other external disturbances while measuring the electromyograph for the human body. This paper deals with the analysis of different biopotential electrodes for measuring electromyography (EMG). This is carried out by analysis of various materials used for manufacturing the electrodes, the noise which is generated, resistivity of the material and also invasive (generates pain while measuring) and non-invasive (does not generate any pain while measuring) electrodes. There are different types of electrodes used for electromyographic measurement, among which needle electrode is used more in clinical measurements. But this electrode produces much signal to noise ratio (SNR) of about 120 dB and produces some pain due to needle electrodes which will be inserted into the skin of human body (invasive) during measurements. So, the surface electrode is placed over the epidermis (outer layer of the skin) of human body, has been analyzed for measuring the electromyographic signals from the particular position of defect (gait analysis, neuropathic and myopathic disorders) in human body, which produces SNR of about 75 dB and temperature coefficient of 0.0038 K^{-1}. These electrodes are made of silver (Ag)/silver chloride (AgCl) which is non-invasive electrode. So, this type of surface electrodes (also disposable surface electrodes) will be simpler and much easier to measure with low cost and also gives more accurate results of EMG measurements from human body without pain during measurements.

Keywords: Electrodes, Electromyography, Noninvasive, Signal to noise ratio, Silver.

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1. INTRODUCTION

In the electromyographic work, the electrodes used are usually of the needle type and surface electrodes (disposable electrodes). These needle electrodes are used for clinical electro-measurements such as neuropathy (measures the activity of the nerves) and myopathy (measures the activity of the muscles). The material used in the needle electrode is of stainless steel. Needle electrodes are used in electromyography (EMG) signal measurements after thorough sterilization. Needle electrodes have various structures and materials used. They are monopolar and bipolar needle electrodes. The monopolar needle electrodes consist of synthetic resin (sticky flammable organic substance) made by polymerizing tetrafluoroethylene, which is at tip of the needle electrode. If the particular electrode is used a greater number of times then the electrodes will lose their synthetic resin. This synthetic resin is also named as Teflon coating. If this situation occurs, that particular electrode should be discarded. The other structure of needle electrode is the bipolar needle electrode, which is double coaxial, i.e. the electrode contains two insulated wires within the hollow tube with a sharp, retractable internal metal core that can be embedded into a vein, an artery, or another body cavity (cannula). These two insulated wires are bared at the tip of the bipolar needle electrode and make contact with the patient. This cannula will act as a ground. The bipolar needle electrodes have no polarity sense and they are electrically symmetrical.

A concentric coaxial core needle electrode contains both the active and reference electrodes in the same structure. It consists of an insulated wire which is exhibited at the tip of the needle electrode. This concentric needle electrode is more suitable and has stable electrical characteristics. Care should be taken while placing the electrodes and also to maintain the electrode in good condition in order to avoid artefacts (errors/spurious signals). These concentric needle electrodes are made of fine platinum wire, in which the needle has the diameter of 0.6 mm. It provides easy penetration when the needle is inserted. The surface area of the tip of needle will be less than 0.005 mm^2 [1]. Multi-element needle electrodes are used to measure signals from each and every individual fiber of muscle tissue [7, 11]. The special needles are used for measuring 14 surfaces down the side of the needle with the diameter of about 25 microns. From the perspective of structure design, needle electrodes are simple in construction. Notwithstanding, edging of the needle to the suitable angle, providing a proper plastic coating, making the needle electrode resistant against heat (thermal) and chemical stresses and ensuring histological suitability is a difficulty in the manufacturing process.

The longer needles are inserted into the brain for measuring the potentials in the specific part of the human brain. These longer needles are particularly located by means of maps or atlas of the human brain. An instrument named stereotaxic instrument which will be fixed to the head, is used to localize an area in the human brain accurately by means of coordinates related to

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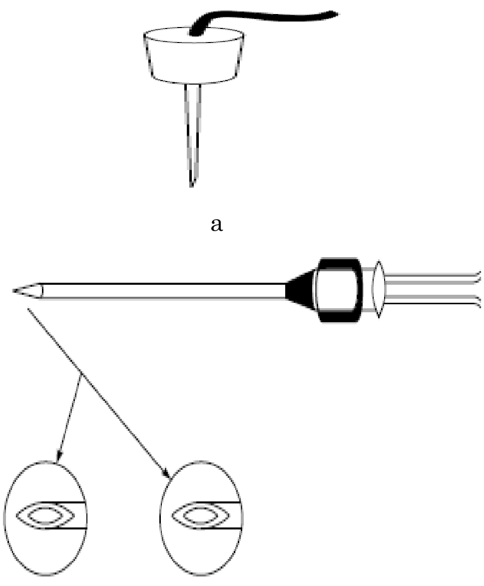
intracerebral structures. Using this apparatus, the measurement is taken periodically. Fig. 1 presents different types of intramuscular needle electrodes. Considering the electrode types with its characteristics, cost, limitations and potential risk, the electrode is chosen in order to measure the best physiological functions of requirement. The generally utilized needle electrode as shown in Fig. 1a has a solitary protected wire inside the cannula of a hypodermic needle, set up by epoxy paste and cut flush with the needle tip. This recording wire, with a recording surface of 150 by 600 μm at the tip, is alluded to the cannula.



a

b

Fig. 1 – Needle EMG electrode (a), hypodermic needle EMG electrode (b)

Another normally utilized electrode is a monopolar needle electrode which is illustrated in Fig. 1b, which is comprised of a protected strong needle aside from the most distal 300 μm at the tip, reference to a surface electrode; in this way, it has a slightly larger pickup area. A considerably small recording area of the electrode is required in order to examine the electrical transmission in single muscle fibers [8, 11]. This electrode with a recording surface of 25 μm is situated in a side port 3 mm once again from the needle tip on the contrary side of the incline [10]. This design helps in limiting the risk of considering muscle strands harmed by the needle tip amid inclusion. Diameter of the take-up region is around 300 μm. The arrangement of large-scale EMG (macro sized) electrode is similar to the single fiber electrode aside from that the distal 1.5 cm of the needle electrode is uncovered. This recording surface, referenced to a surface electrode on the skin, has a huge pickup region and can along these lines identify the motor unit territory.

The ground electrode for EMG comprises as a rule of a directing strip which is embedded into a saline splashed lash and folded over the patient's appendage. The ground electrode is typically situated over hard (bony) structures as opposed to over vast (large muscles) bulks, in the region of the recording and stimulating electrodes, and where conceivable, is equidistant from them. Surface electrodes are utilized for recording net electrical movement from a specific gathering of hidden muscles in nerve velocity estimations. A solitary surface electrode may likewise be utilized as the reference electrode with monopolar needle terminals of the electrode. Surface electrodes can be effortlessly and immediately joined and for the most part they are agreeable to wear over extensive stretches [13].

For all the electrode composes, extra measures can be taken to fasten the electrode cabling to the patient body to limit development of motion artefacts. Normal sticky tape, snare and circle latches (loop fasteners), and flexible ties (elastic straps) are usually used to secure cabling onto the body, yet never the electrodes as this will influence the readings.

2. RELATED WORKS

Diana C. Toledo-Pérez et al. [1] studied a correlation of the arrangement exactness dependent on the distinctive number of surface EMG (sEMG) signal channels (one to four) put in the correct lower appendage of healthy subjects. The examination is performed utilizing waveform length, mean absolute values, slope sign changes and zero crossings; these attributes contain the component vector. The calculation utilized for the arrangement is the support vector machine subsequent to applying a principal component analysis to the highlights. The outcomes demonstrate that it is conceivable to arrive at over 90 % of order precision by utilizing 4 or 3 channels. In addition, the distinction acquired with 500 and 1000 examples, with 2, 3 and 4 channels, is not higher than 5 %, which implies that expanding quantity of channels does not ensure 100 % accuracy in the characterization.

Luke J. Heales et al. [3] utilized ultrasound imaging, neurovascular structures were distinguished along the way of FDP (Flexor Digitorum Profundus) electrode inclusion at the intersection of the proximal and center third of the ulna, reciprocally, in ten healthy people. Additional profundity was looked at between the foremost and average methodologies for the mid muscle tummy (belly) and focused on inclusion to the forefinger fascicle of FDP. For example, the ulnar vein was shallow to the FDP muscle when seen anteriorly and was past the uttermost fringe of FDP when seen medially. Contrasted with the foremost methodology, the average inclusion profundity was 1.5 cm (95 % CI 1.4-1.7, $p < 0.001$) less to the mid-midsection of FDP and 0.6 cm (95 % CI 0.4-0.7, $p < 0.001$) less to the pointer fascicle of FDP. The average methodology includes less profundity and lower chance for aperture of neurovascular structures when intramuscular terminals are embedded into the FDP muscle.

Paolo Cattarello et al. [6] explored the electrode-skin interface and looked at changed electrode types and skin medicines. The impacts, assessed regarding singular electrode-skin impedance, impedance bungle and commotion, because of the terminal sort (wet or dry contact), the skin treatment type (scraped spot, keratolytic operators, sweat) and the contact time, were examined. The between and intra-subject repeatabilities of the estimations were considered. The cathodes were picked to be effectively incorporated into textures and utilized for high density surface electromyography (HDsEMG). It is inferred that keratolytic operators (connected for 5 min) and plating of Ag electrodes with

AgCl (in dry contact conditions) have restricted impact, while skin scraped area and hydration (by perspiration) and the utilization of conductive gel/glue at the interface have a lot more prominent impact on decreasing contact impedance and commotion.

C. Pylatiuk et al. [9] described that the electrode materials incorporate four unique polymers with conductive burden and a texture of strings covered by a conductive layer. Various criteria are utilized to assess surface EMG recording: the sign quality, including signal-to-noise ratio (SNR), and impedance in long haul monitoring. The point of the examination is to discover an EMG electrode that takes into account both silicone liner and material mix for control of recovery gadgets for quadriplegics with a fractional remaining capacity of the upper appendage and for multifunctional prosthetic hands [16]. Other than electrical properties, the biocompatibility and the wearing solace must be considered to accomplish a wide acknowledgment by the patients.

He Huang [12] described a diminished number of electrodes and the situation required to separate adequate neural control data for precise recognition of user motion intents. An electrode determination algorithm was applied to the HD EMG recordings from every one of four TMR (Targeted muscle re-innervation) amputee subjects. The outcomes demonstrate that when utilizing just 12 chosen bipolar electrode, the normal precision over subjects for characterizing 16 development aims was 93.0 ($\pm$ 3.3) %, only 1.2 % lower than when utilizing the whole HD electrode supplement.

Bhullar et al. [19] designed and developed a particular non-obtrusive surface terminal to think about myoelectric signals. The electrode recording surfaces are two concentric steel rings. A third ring joined to the packaging of the surface electrode is the ground (earth) contact. The rings are isolated from one another by synthetic resin (Teflon), the protecting material. The small-scale surface region of the electrode plates, the small-scale physical size and the concentric course of action deliver the impact of account flags fundamentally from strands close to the hub of the terminal and in this way make the cathode substantially more specific. The concentric ring rather than the ordinary uninvolved electrode setup additionally deters the issue of terminal arrangement with respect to the heading of the muscle strands. The consequences of tests embraced with these terminals demonstrated that it could get individual motor unit action potentials at moderate power levels.

Crenner et al. [20] constructed a notable electrode which permits recording of electrical signs from their different muscular layers, particularly to gather electromyographic signs of the stomach and intestine as a functional unit (gastrointestinal tract). The dynamic terminal is encompassed by a ring which stays away from the account of meddling signs.

3. BIO-POTENTIAL ELECTRODES AND ELECTRICAL CHARACTERISTICS

Interface is the surface regular to two zones or the gathering point between two electrical or electronic circuits. Appropriate coordinating or interceding is required for fruitful interfacing between the two substances. In biomedical designing, two sorts of interfacing might be considered, which are (i) interfacing with skin and electrode, and (ii) interfacing with electrical or electronic circuits connecting one gadget with another [15]. So as to gauge and record possibilities and, subsequently, flows in the body, it is important to give some interface between the body and the electronic estimating contraption/circuit. This interface capacity is done by biopotential electrodes.

The possibilities of estimating the biopotential electrode characteristics are maximum at less time frames. In a perfect world this current ought to be exceptionally little. Notwithstanding, in practical cases, it is never zero. Biopotential electrodes should in this manner have the ability of directing a current over the interface between the body and the electronic estimating circuit. The electrode really does a transducing capacity, since current is conveyed in the body by particles, though it is conveyed in the electrode and its lead wire by electrons. Along these lines the electrode must fill in as a transducer to change an ionic current into an electronic current. This significantly confuses cathodes and spots of measurement activities [1, 6].

Hypothetically, two kinds of electrodes are conceivable: those that are flawlessly polarizable and those that are splendidly nonpolarizable. This grouping alludes to what befalls a terminal when current goes among it and the electrode. Consummately polarizable electrodes are those in which no real charge crosses the electrode electrolyte interface when a current is connected. Obviously, current must be present over the electrode electrolyte interface. However, this current is a relocation current, and the terminal carries on just as it were a capacitor. The nonpolarizable terminals are those in which current passes unreservedly over the electrode electrolyte interface, requiring no vitality to make the progress. Consequently, for nonpolarizable terminals there are no overpotentials. Neither of these two electrodes can be manufactured; be that as it may, some reasonable electrodes can verge on obtaining their attributes. Electrodes are made of pure metal, come close to acting as consummately polarizable electrodes. The electrical qualities of such an electrode produce a solid capacitive impact, and are not appropriate for viable applications.

The silver-silver chloride electrode is a real time practical electrode that methodologies the qualities of a consummately nonpolarizable electrode and can be effectively manufactured in the research center [4]. It is an individual from a class of electrodes, every one of which comprises of a metal covered with a layer of marginally solvent ionic compound of that metal with a reasonable anion. The entire structure is inundated in an electrolyte containing the anion in generally high focuses.

The electrical attributes of electrodes have been the subject of much examination. Frequently the current-voltage attributes of the electrode electrolyte interface are observed to be nonlinear, and, thus, nonlinear components are required for demonstrating electrode conduct. In particular, the attributes of an electrode are touchy to the current going through the terminal, and the electrode qualities at generally high current densities can be viewed as not the same as those at low current densities. The attributes of electrodes are likewise waveform-subordinate/dependent. At the point when sinusoidal flows are utilized to gauge/measure the electrode's circuit conduct, the qualities are additionally frequency dependent. For sinusoidal data sources, the terminal attributes of an electrode have both a resistive and a reactive agent and component. The straightforward arrangement equivalent circuit, in any case, does not present the whole picture. If we consolidate the resistance and capacitance equivalent circuit with a voltage source speaking to the half-cell potential and a series representing to the interface impacts and resistance of the electrolyte, we can land at the biopotential electrode equivalent circuit model as depicted in Fig. 2.

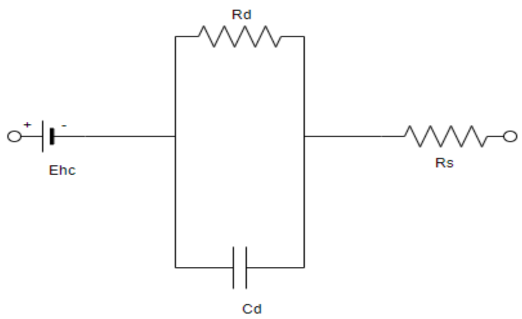


Fig. 2 – Equivalent circuit model of bio-potential electrode

At the point when biopotentials are recorded from the outside of the skin, we should think about an extra interface, i.e. the interface between the electrode electrolyte and the skin, so as to comprehend the conduct of the electrode terminals. In coupling a terminal to the skin, we for the most part utilize a straightforward electrolyte gel containing Cl as the primary anion to keep up great contact. On the other hand, we may utilize an electrode paste, which contains Cl and has the consistency of hand salve. The interface between this gel and the electrode is a terminal electrolyte interface, as portrayed previously. Notwithstanding, the interface between the electrolyte and skin is unique and requires some clarification. To audit the structure of the skin, let us take a gander in Fig. 3.

The skin comprises of three chief layers that encompass the body to shield it from its condition and that likewise fill in as suitable interfaces. The peripheral layer, or epidermis, assumes the most significant spot in the electrode skin interface. This layer, which comprises of three sublayers, is always re-establishes itself. Cells partition and develop in the most profound layer, the stratum germinativum, and are dislodged outward as they develop by the recently shaped cells underneath them. As they go through the stratum granulosum, they start to pass on and lose their atomic material. As they proceed with their outward voyage, they ruffian further into layers of level keratinous material that structures the stratum corneum, or horny layer of dead material on the skin's surface. These layers are continually being worn off and supplanted at the stratum granulosum by new cells. The epidermis is along these lines is always showing signs of change of the skin layer, the external surface of which comprises of dead material that has diverse electrical attributes from live tissue [18]. The more profound layers of the skin contain the vascular and apprehensive parts of the skin just as the perspiration organs, sweat glands, and hair follicles. These layers are like different tissues in the body and, except for the perspiration organs, they do not offer any one of a kind electrical trademark on the skin.

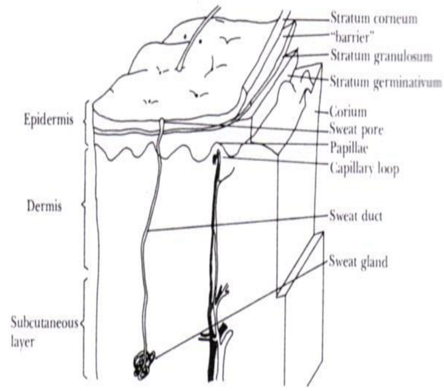


Fig. 3 – Crosswise illustration of skin

4. EXPERIMENTATION OF DIFFERENT ELECTRODES

Throughout the years, a wide range of sorts of electrodes for chronicle different possibilities on the body surface have been created. The electrodes might be comprehensively characterized into the two classes, to be specific, the body surface electrodes, which are utilized on the outside of the body, and internal electrodes, which are embedded into the body as needles, wires, or embedded electronic circuits, for example, radio telemetry transmitter.

1) Body surface electrodes.

Among the various types of body surface electrodes, the following are worth mentioning [20]: metal plate, floating, flexible, suction electrodes and dry electrodes.

i) Metal surface (plate) electrode.

One of the most habitually utilized types of biopotential detecting cathodes is the metal-plate electrode. In its essential structure, it comprises of a metallic conduit in contact with the skin. An electrolyte gel is utilized to set up and keep up the contact. Fig. 4 demonstrates a few types of this electrode.

These electrodes are widely used for various measurements in human body such as electrocardiogram (ECG) and EMG for measuring the heartbeat, muscle and nerve disorders and so on. Fig. 4 is used for measuring both ECG and EMG but varying the number of electrodes and type of measurement required. Fig. 4a can be

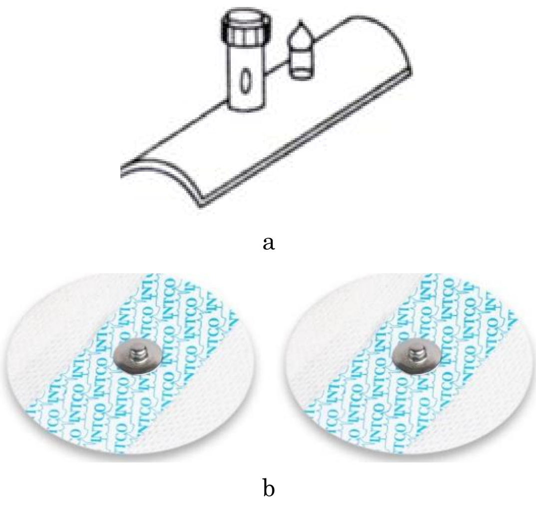


Fig. 4 – Different types of metal surface electrodes: metal to body surface electrodes (a), disposable electrodes (b)

reused for many times for different measurements. Moreover, this electrode uses a screw to adjust the body surface, whereas in the case of disposable electrodes (Fig. 4b) it cannot be reused. It is one-time use electrode. It is stick to the body surface by using electrode paste. That electrode paste will absorb the electrical signal from body surface and depict in the system. This disposable surface electrode is more convenient and easy to use with low cost comparatively.

ii) Floating electrode.

We realize that one wellspring of movement ancient rarity in biopotential terminals is the twofold layer of charge at the cathode electrolyte interface. To diminish this antique, skimming electrodes are utilized, which offer a reasonable method and balance out the interface precisely. A skimming electrode is known as a top-cap terminal; its inward structure appears in Fig. 5.

The chief element of the terminal is that the real electrode component or metal plate is recessed in a depression, so it does not interact with the skin itself. Rather, the component is encompassed by electrolyte gel in the cavity. The cavity does not move regarding the metal plate, so it does not create any mechanical development of the two-fold layer of charge.

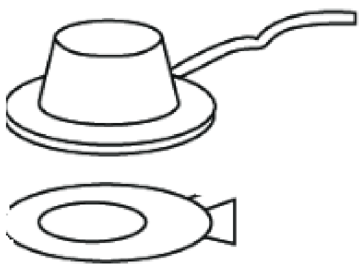


Fig. 5 – Recessed electrode with top-cap

Practically speaking, the electrodes are loaded up with electrolyte gel and after that connected to the skin surface by methods for two sided sticky tape ring, as appeared in Fig. 5. The electrode component can be a circle made of metal, for example, silver, and regularly it is covered with AgCl (silver chloride). Another every now and again experienced type of the skimming electrode utilizes a sintered Ag-AgCl pellet rather than a metal circle. These electrodes are observed to be very steady and are reasonable for some use.

iii) Flexible electrodes.

Strong electrode depicted so far cannot comply with the adjustment in body-surface geology, which can bring about extra movement antiquity. To dodge such issues, adaptable cathodes have been created [5]. A carbon-filled silicone elastic compound as a slight strip or circle is utilized as the dynamic component of an electrode. A stick connector is pushed into the lead connector opening, and the terminal is utilized similarly as a comparative kind of metal-plate cathode. Adaptable cathodes are particularly significant for observing untimely new born children. Terminals (electrode) for distinguishing the ECG and breath by the impedance system are joined to the chest of untimely babies, who most often weigh less than 2500 g. Regular terminals are not suitable.

iv) Suction electrodes.

An adjustment of the metal-plate electrode that requires no lashes or cements for holding it set up is the suction electrode. Such electrodes are much of the time utilized in electrocardiography as the precordial (chest) drives, since they can be put at specific areas and used to take a chronicle. They comprise of an empty metallic barrel shaped electrode that reaches the skin at the base. A fitting terminal/electrode for the lead wire is appended to the metal chamber, and an elastic suction bulb fits over its other base.

Electrolyte gel is put over the reaching surface of the electrode, the bulb is crushed and the electrode is then set on the chest divider. The bulb is discharged and applies suction against the skin, holding the electrode get together set up. This electrode can be utilized distinctly for brief timeframes; the suction and the weight of the contact surface against the skin can cause aggravation.

v) Dry electrodes.

All the surface electrodes depicted so far require an electrolyte gel to set up and keep up contact between the electrode and the skin. Late advances in strong state electronic innovation have made it conceivable to record surface biopotentials from electrodes that can be connected straightforwardly to the skin without a middle of the road layer of electrolyte gel. The noteworthy element of these electrodes is an independent, high-input impedance enhancer. A case of a dry-electrode framework is created by [6].

2) Internal electrodes.

Percutaneous terminals/electrodes are those utilized for checking fetal heartbeat. For this situation it is alluring to get the ECG from the hatchling during work by direct association with the introducing part (normally the head) through the uterine cervix (the mouth of the uterus). The embryo lies in a shower of amniotic liquid that contains particles and is conductive, so surface terminals by and large don't give a satisfactory ECG because of the shorting impact of the amniotic liquid. Consequently, terminals used to acquire the fetal ECG must infiltrate the skin of the baby. A sharp-pointed test in the focal point of a suction cup can be connected to the fetal introducing part.

In considering the electrophysiology of sensitive cells, it is frequently essential to quantify potential contrasts over the physical layer. To have the option to do this, we should include a terminal inside the cell. Such electrodes must be little as for the cell measurements to abstain from causing genuine cell damage and along these lines changing the cell's conduct. These electrodes are known as microelectrodes and they might be of three sorts, to be specific, metal microelectrode, upheld metal microelectrodes and micro-pipet electrodes [2]. The innovation used to create transistors and incorporated circuits can likewise be utilized to micromachine little mechanical structures. This system has been utilized by a few specialists to deliver metal microelectrodes.

5. RESULTS AND DISCUSSION

These different electrodes are used for various purposes of measurements in human body such as electromyography, electrocardiogram, electroencephalogram etc. The main is to identify the major electrodes used for the measurements of electromyography (EMG) signal from various locations in human body. That electrode will detect the muscle and nerve disorders. Depending on the various parameters taken into account, the electrodes have been classified which as tabulated in Table 1. The major parameters include the materials which the electrodes are made of, resistivity with the corresponding temperature coefficients and also the SNR is calculated for each electrode as follows:

In general, $SNR = P_{signal}/P_{noise}$

$$SNR = \frac{E\left[S^2\right]}{\sigma^2 N}, \quad (1)$$

where, E denotes the expected value, S represents the random variable and σ represents the random noise generated. The SNR of different electrodes in decibels (dB) can be computed by using equation (2):

$$SNR_{dB} = 10\log_{10}\left(SNR\right). \quad (2)$$

The resistivity and temperature coefficient of materials are constant values at their specific temperatures, i.e. the resistivity of the material is computed at 20 °C and the corresponding temperature coefficient is calculated. Table 1 shows the analysis of different types of electrodes.

Table 1 – Analysis of different electrodes

Electrodes	Material	Resistivity (Ωm)	Temperature coefficient (K^{-1})	SNR in dB	Purpose of measurements
Metal surface (plate) electrodes	Molybdenum/ molybdenum oxide	5.34×10^{-8}	4.8×10^{-6}	250	EMG or EEG
Floating electrodes	Silver chloride (AgCl)/silver	1.59×10^{-8}	0.0038	75	EMG or ECG
Flexible electrodes	Carbon filled silicon elastic compound and Mylar film with AgCl	1.59×10^{-8}	0.0038	77	Born babies under 2.5 kg for ECG
Suction electrodes	Silver chloride (AgCl)/silver or nickel	1.59×10^{-8} for silver 6.99×10^{-8} for nickel	0.0038 for silver 0.006 for nickel	75 for Ag 84 for Ni	ECG
Dry electrodes	Silver/silver chloride or stainless steel	1.59×10^{-8} for silver 6.90×10^{-7} for stainless steel	0.0038 for silver 0.00094 for stainless steel	75 for Ag 120 for stainless steel	EMG
Internal electrodes/ needle electrodes	Stainless steel	6.90×10^{-7}	0.00094	120	EMG

Table 2 – Electrode materials

No. of electrode	Name of the materials
1	Molybdenum
2	Silver
3	Nickel
4	Stainless steel

The SNR value is computed for the corresponding materials used for different types of electrodes as depicted in Table 1, Table 2. From these electrodes, the major material used is silver (Ag)/silver chloride (AgCl) which reduces the SNR and also has better resistivity and temperature coefficient. The EMG signal from various locations of human body can be measured using surface electrodes (disposable electrodes), dry electrodes and needle electrodes which are mostly used in clinical laboratories [20]. According to the inspection done, the surface electrode (disposable electrode) can be used for measuring EMG signals due to its reduced SNR, which uses silver/silver chloride material for manufacturing it. Moreover, this electrode is non-invasive and also gives much accurate results compared to other dry electrodes, in contrast to the case of needle electrode which is invasive. Many patients cannot tolerate a small pain especially old age patients. So, in that case surface electrode (disposable electrode) is simple and it is easy to obtain accurate results.

6. CONCLUSIONS

In utilizing metal electrodes for estimation and incitement, we ought to comprehend a couple of functional focuses. The main point is the significance of building the terminal and any pieces of the lead wire that might be presented to the electrolyte of the majority of similar materials. Besides, a third material, for example, solder ought not to be utilized to associate the terminal to its lead wire except if it is sure that this material will not be in contact with the electrolyte. At the point when sets of electrodes are utilized for estimating differentials, for example, in identifying surface possibilities on the body or interior possibilities inside it, it is obviously better to utilize a similar material for every terminal, on the grounds that the half-cell possibilities are almost equivalent. This limit is conceivable immersion impact on account of high increase direct-coupled enhancers. Terminals put on the skin's surface tend to fall off. Lead wires to these surface terminals ought to be incredibly adaptable yet solid. In the near future, this electrode will be used for measurements of EMG signals with necessary amplifier and filter circuitry in order to obtain good results of measurements.

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Аналіз різних біопотенційних електродів, що використовуються для електроміографії

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Вимірювання електроміографічних (ЕМГ) сигналів від людського тіла за допомогою електродів стає складною задачею завдяки використаним матеріалам, шуму, температурному коефіцієнту, болю та іншим зовнішнім порушенням при вимірюванні електроміографа для людського тіла. У роботі представлений аналіз різних біопотенційних електродів для ЕМГ вимірювань. Він здійснюється шляхом аналізу різних матеріалів, що використовуються для виготовлення електродів, шуму, який генерується, питомого опору матеріалу, а також інвазивного (викликає біль під час вимірювання) та неінвазивного (не викликає жодного болю під час вимірювання) електродів. Відомі різні типи електродів, що використовуються для ЕМГ вимірювань, серед яких голчастий електрод більше використовується для клінічних вимірів. Але цей електрод дає велике співвідношення сигнал/шум (SNR) приблизно 120 дБ і викликає деякий біль через голчасті електроди, які будуть вставлені в шкіру людського тіла (інвазивний електрод) під час вимірювань. Так, поверхневий електрод, розміщений над епідермісом (зовнішнім шаром шкіри) людського тіла, проаналізований для вимірювання ЕМГ сигналів з конкретного положення дефекту (аналіз ходи, нейропатичні та міопатичні розлади) в організмі людини, який дає SNR приблизно 75 дБ і температурний коефіцієнт 0,0038 K^{-1}. Ці електроди виготовлені з срібла (Ag)/хлориду срібла (AgCl), який є неінвазивним електродом. Таким чином, цей тип поверхневих електродів (також одноразові поверхневі електроди) буде простішим та значно легшим для вимірювань, з низькою вартістю, а також дасть більш точні результати вимірювань ЕМГ від людського тіла без болю під час вимірювань.

Ключові слова: Електроди, Електроміографія, Неінвазивний, Співвідношення сигнал/шум, Срібло.