DESIGN AND INVESTIGATION THE OPERATION OF TEXTILE BASED ELECTRODES FOR ELECTROTHERAPY

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ABSTRACT

Electrostimulation is a way of treatment various nerve and muscle injuries as well as acute and chronic pain conditions. The electrotherapy which is increasingly used in physiotherapy, muscle is exposed to an electrical pulse in order to activate excitable tissue using external electrodes with the aim of building muscle strength, enhancement healing, improvement in patient's mobility or reducing painTextile based electrodes are significantly noticed in the aspects of being flexible and re-usable and no needs of hydrogels, thereby avoiding skin irritation and allergic reactions and enhancing user comfort. This article presents a kind of textile based electrodes made of conductive yarns containing stainless steel/plyester blend fiber. The embroidery technique was used to prepare the textile based electrodes.Samples were examined on 10 people with pain in their bodies in a hospital without being moisturised. The purpose of this study is to asses the performance of 3 different textile based electrodes, considering the conductivity of the yarns which have been used to produce textile based electrodes, the usfulness of them for electrotherapy and comparing them with rubber electrodes commonly are used in clinics regularly.

KEYWORDS

Electrostimulation; Electrotherapy; Rubber electrode; Textile electrodes; Conductive yarn; Embroidery.

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INTRODUCTION

"Smart textiles" are novel topics in research area which is related to new generation of fiber assemblies and apparel systems that are able to react with, sense and be adapted to surrounding conditions or stimuli in a manual or programmed manner. Fiber and also textile based electronics have extreme flexibility as well as wearing comfort. In addition, their fabrication is low-cost and have environmentally friendly process by means of conventional facilities, often with no need of special conditions. The most relevant definition of smart textiles is textiles that interact external situations [7]. To date, conductive textiles or in another words electro-conductive textiles have wide variety of applications in smart textiles are currently under investigation by many researchers. There are three ways to make a fabric conductive, using conductive fiber materials, conductive fiber coatings, or conductive coating or finishing methods on the whole textile fabrics [2].

Electrotherapy involves a wide range of techniques and devices and used as longterm treatment for post-acute rehabilitation patients delivered over a period of eight to sixteen weeks. In this type of therapy human body is exposed to a low-level current in order to become activated or stimulated. In contrast of internal electrodes used with in the body surface electrodes are applied on the skin. Among surface electrodes, the disposable rubber electrodes, need using an additional hydrogel or electrode cream as an electrolyte interface between the skin and the electrode in order to improve skin contact and ensure a continuous current flow. As well as investigating the contact between the electrode and human skin, natural changes in the skin such as changes of humidity, temperature, structure should be paied atteintion. The surface resistance of the electrode must ne in a small value and also it is one of the most significant parameters of a proper electro stimulation process. In order to have a lower surface resistance yarns characterised by high conductivity for instance silver polyamide yarns or cotton yarns wrapped round by stainless steel can be used [10].

Previous works investigated suitable stimulation parameters using TENS electrodes, designed garments able to deliver functional electrical estimulation[9]. In spite of the majority medical use of rubber electrodes, they have been found to cause skin irritation, shocking and skin burns in some patients. While wearable conductive textile electrodes provide alternative, skin comfort and high elasticity for users. Baheti et al. dealt with the deposition of silver particle onto knitted fabrics for possible application in electrotherapy. A knitted fabric with deposited silver particles was used in electrotherapy and its operation on some properties as well as electrical conductivity, physiological comfort, antibacterial, and durability were investigated. When there is a variety of human body movements small electrical resistance changes were observed during the extension to 80% and as the results, it can be noticed that the electrical resistance will increase significantly after the 90% extension. Besides, as other findings of this paper, it can be noted that no significant changes in fabric properties such as air permeability, water vapor permeability, fabric porosity, and conductivity were observed [1].Three types of knitwear with a similar surface weight with different raw material composition were fabricated by Skrzetuska et al. Embroidery machine and film printing were used in stimulating electrode fabrication. Friction, washing and mechanical tests were investigated. As a result, they found that the best textile material for film printing process in electrode fabrication is viscose knitwear[8]. Garments with the ability to deliver functional electrical stimulation were designed by Moineau et al. Electrodes knitted by means of conductive yarn were moistened before use[6]. Another study on dry and wet textile electrodes in electrotherapy demonstrated that using dry electrodes can cause pain when the current is in a low range; on the other hand, the wet textile based electrodes which were tested alongside the dry and common hydrogel electrodes showed no sign of pain during the process which is due to pain-sensing fiber that can be activated more feasible with the dry electrodes than the wet and hydrogel ones [11]. Considering the differences between wet and dry electrodes, there is another study which confirms the preference of wet textile electrodes over the dry ones. Euler et al has compared six various of knitted electrodes in wet and dry state. The study shows that wet electrodes have less contact impedance than dry knitted electrodes. From the results it can be noted that dry textile electrodes have their best performance with an uneven surface. At the same time the wet textle based electrodes are more acceptable with a smooth surface. Nevertheless it is noticed that the dry textile based electrodes performance can be improved by putting pressure on the system[3]. Liu et al in a novel study has investigated a textile based electrode for electrotherapy which had an acceptable result in reducing pain on subjects[5]. Hunold et al has investigated a novel textile based electrode which is integrated with flexible caps; also a comparison between these novel electrodes and conventional rubber electrodes were studied. The results showed that the flexible cap used with textile based electrodes made them more comfortable as wearable electrodes[4].

EXPERIMENTAL

Materials

In this study textile based electrodes are made of Stainless steel/polyester staple fiber blend yarn (produced by Xiamen JL-fiber Science and Technology Co. Ltd., Xiamen, China). The fineness of stainless-steel fiber was 12 microns. Properties of the conductive yarns are presented in Table 1. Electrodes were made on a stretchable woven fabric in 6*6 square centimeter dimension. The weave design of this fabric was plain. Mass per unit area of the used fabric was 0.0113 g / cm^2. A couple of electrodes were prepared from each yarn, one of them as phase and the other one as zero, therefor we had six samples that their features are noted in Table 2. Surface electrical resistance of each electrod were measured by using a foure prob. The warp yarn of based woven fabric was multifialment Polyester/Spandex(75den/20den) intemingled yarn. Weft yarn was Polyester/viscose(65/35%) ring spun yarn with linear density of 20 tex. The connector attached to the surface of each electrode by using conductive silver glue. Rubber electrodes has been used as reference one in order to evaluate the performance of the textile based electrodes. Prepared textile based electrodes are shown in Fig 1. A two-channel Berjis ST-90 physiotherapy system was used as an electricity resource to provide electrical current. That provided electrical current transferred to the surface of the textile based electrode through a wire which used as a connector. The rubber electrode is shown in Fig 2.

Table 1. Properties of the yarn

Properties / Yarn Code	Blend Ratio (Stainless steel/PET)	Strength (cN/Tex)	Linear Resistance (Ω/cm)	Diameter (µm)	Extension (%)
A	80%/20%	32.22	5.31	447.14	6.78
B	40%/60%	120.05	23.07	249.46	3.24
C	28%/72%	125.84	29.82	248.25	3.08

Table 2. Properties of the samples

Electrode Code	Yarn Code	Surface electrical resistance ($\Omega/square$)	Weight (g)	Thickness (mm)
1	A	2.25	1.83	1.28
2	B	16.6	1.09	0.95
3	C	26	1.72	1.15

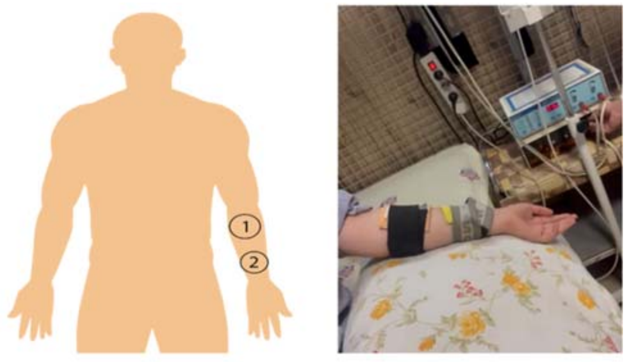
(a) (b) (c)

Figure 1. Textile based electrodes: (a): The electrode from yarn C and its connector, (b): The electrode from yarn B and its connector, (c): The electrode from yarn A and its connector

Figure 2. Rubber electrode

Methods

In this study conductive yarns containing 28, 40 and 80 percent of stainless steel fibers and 72, 60 and 20 percent of polyester fibers, respectively were used to develop textile based electrodes with the dimension of 6*6 square centimeter. Conductive yarns were embroidered on mentioned fabric by means of Jack JK-9100B sewing machine. Moreover, connectors have been used in order to connect the textile electrodes to the two-channel Berjis ST-90 physiotherapy system. Textile based electrodes were placed on different parts of patient's body such as patient's arm, leg, calf, knee and back. As an example, electrodes position on the patient's arm is illustrated in Fig 3(a) and also Fig 3(b) shows textile based electrodes which was worn around the forearm of one of the authors. These textile based electrodes were located in wet spong pads. Spongy pads are shown in Fig 4.



(a) (b)

Figure 3. (a) electrodes positions on the patient's arm, (b) clinical test of textile based electrodes on forearm position.

Figure 4. Spong pads.

RESULTS AND DISCUSSION

In our experiments we compared the performance of textile based electrodes with conventional rubber ones. Results showed that textile based electrodes had a comparable performance with rubber electrodes during the electrotherapy. We confirmed that the textile based electrodes had a desirable current during the electrotherapy for all the patients on all parts of their bodies. According to the results, textile based electrodes illustrated similar electrical current with rubber electrodes as the patients were therapied and no clear differences has been observed in the performance of rubber and textile based electrodes. The electrical conductivity of electrodes could be one of the main factors which has been considered in this study. The result revealed that the electrical current using dry textile electrodes did not increased as the conductivity increased and transferred current did not change. All the textile based electrodes with different conductivity performed equally.

CONCLUSIONS

In this study textile based electrodes, which prepared by swing conductive stainless steel yarns on a stretchable woven fabric by using Jack JK-9100B sewing machine, have been presented as an alternative for conventional rubber electrodes. Both electrodes were placed in a pad and no skin irritation was observed while using pad. The results showed that textile electrodes performed well throughout the therapy. Furthermore, according to the result, increasing the conductivity won't lead to improve textile electrodes efficiency in transferring the electrical current. Compared to the rubber electrodes prepared electrodes exhibited similar and comparable performance. It seems that the use of textile based electrodes for using in electrotherapy instead of conventional electrodes has many potential and in future we aim at work on the life time and durability of these electrodes and also effect of dimension and structure of them on their performance.

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