sEMG MEASURING BY GARMENTS

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This paper presents the recent actions in the field of integrating sEMG electrodes to the garments. sEMG is an abbreviation from surface electromyography, which is a method to study muscle activity. Traditionally, disposable metallic (Ag/AgCl) EMG electrodes with conductive paste are glued onto the person under test. Since 2001, Clothing Plus Oy, and Mega Electronics Ltd have worked together in order to develop working prototypes of EMG garments. Five years later, ConText project started with the objective to develop new textile integrated contactless EMG electrodes. ConText technology under development will be tested in the form of EMG vest.

sEMG measuring, clothing application, contact and contactless textiles sensors

1 Introduction

sEMG is an abbreviation from surface electromyography, which is a method to study muscle activity. EMG technique has similarities with ECG (electrocardiography) and EEG (electroencephalography) methods. Traditionally, disposable metallic (Ag/AgCl) EMG electrodes with conductive paste are glued to the skin upon the muscles of the person under the test. The following picture (Figure 1.) presents a test person with glued EMG electrodes.

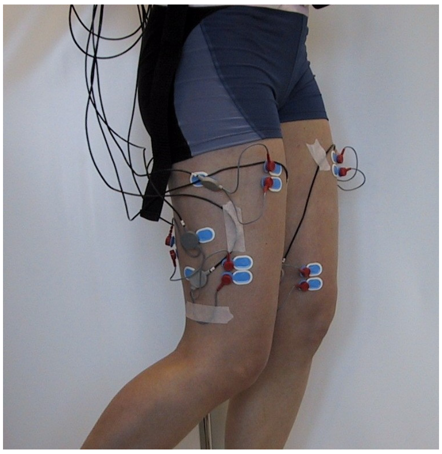

Figure 1. *Test with the traditional glued EMG electrodes*

Before, it is possible to start an EMG measuring a professional is needed to glue the electrodes to the right places on the testees's body. This procedure takes time and is very complicated to be reproduced reliably for later follow-up measurement. Glued electrodes on the skin are uncomfortable, and some testees even may get skin irritation. The wires between the electrodes and EMG measurement device often disturb the test person in her/his duties. The loose wires can even prevent the measurements in some working environments or in field circumstances, when the testee must use heavy or task specific safety clothing. If the testee starts to sweat, there is a risk that glued electrodes begin to slide along the skin or even drop away thus interfering measurement .reliability.

Garments have big potential in body monitoring as they cover a large area on the user's body. In addition, garments serve a good base to hold the electrodes and the needed wires. Besides, they are a very natural base for the electrodes as everybody wears cloths every day. Potential of the body monitoring is especially interesting from the health monitoring, and disorder prevention or observing point of view. In the area of ergonomics, EMG monitoring can be used to evaluate and advice general work place ergonomics, identify individual overloading factors and work related injuries as well as to improve working tool and furniture design. Opportunity for comfortable long term monitoring gives new possibilities to ergonomics and gives an opening for developing new well-being tools. European Commission has noticed the potential of integrating electronics and body sensors to textiles and garments as can been seen from the growing amount of the projects the commission gives co-finance in this area [1].

2 Prototype garments with textile EMG electrodes

2.1 *Development of the EMG garments*

Since 2001, Clothing Plus Oy and Mega Electronics Ltd have worked together in order to ease sEMG measuring in non-laboratory environments by the help of EMG garments. Clothing Plus Oy focuses in developing textile components for the electronics industry. In addition, Clothing Plus has production know-how and facilities, whereas Mega Electronics is specialized in the EMG monitoring technology and application specific analysis methods. This cooperation has led to the working prototypes of the EMG garments.

Prototype EMG garments look like normal sport or underwear cloths, except they contain textile electrodes and signal transmission wires for sEMG measuring. Tight-fitting garments are made of flexible knitted fabric, whereas electrodes are made conductive woven band or knitted net (between 10...20 Ω / 10 cm), and coated conductive yarn (< 5 Ω / 10cm) with a support material between electrode and fabric. Garments stand well hand washing, and also machine washing to some extend. During measuring, the user carries a small data logger/ transmitter, which is connected to the garment by a special connection adapter. In the garment, electrodes are placed to measure large muscles or muscle groups like front and rear tights, peroneals, biceps, and shoulder muscles. Garments have been made in two different sizes (S & M), however it has been challenging to find proper sizing and placement for the electrodes to be able to measure anatomically different users types with one size garment. Textile electrodes are much larger than the traditional ones.

Figure 2. *Testee person is wearing EMG trousers and shirt with textile electrodes.*

The size varies depending on the muscle or muscle group to be measured, but the typical size of one electrode is about 3 * 10 cm, but electrodes are naturally used in pairs. Electrodes need to be in tight skin contact, and an intermediate agent like water or body moisturising cream needs to be added on the electrodes before measuring. The Figure 2 shows a user, who is wearing EMG trousers and shirt.

2.2 *Testing and validation*

The prototypes have been field tested in the area of rehabilitation, ergonomics, and sports. One paper has been presented of the usability comparison test between the traditional sEMG method and EMG garments. [2] In 2006-2007, a research group of Neuromuscular Research Centre at University of Jyväskylä in Finland conducted feasibility study to validate the use of textile electrodes embedded into shorts. At the same time the Department of Physiology at University of Kuopio in Finland evaluated and chose EMG garments to be used in their ongoing research project to survey work loading profiles.

2.3 *Results and future steps*

The usability study published by Department of Physiology at University of Kuopio concluded that textile-integrated EMG measurement is appropriate in situations where it is possible to use skin-tight clothes. Method based on an intelligent garment is more feasible compared to the traditional way to measure muscle activity especially in dynamic work and it can be used everywhere and almost in every situation. The traditional way to measure EMG is useful in static measurements, like in laboratory circumstances, whereas using intelligent garment it is also possible to record EMG data during user's daily routines. The measurements can be exploited in sport activities, during rehabilitation after a trauma or also in a number of suitable applications in ergonomics.

Results of the feasibility study by of Neuromuscular Research Center at University of Jyväskylä showed that the textile electrode technique is a valid and feasible method for assessing the level of muscle activity and it can make EMG measurements very easy in the field conditions for athletic and rehabilitation purposes. The study results will be published in two articles in scientific publications during 2007.

A prototype EMG garment was evaluated by Department of Physiology at University of Kuopio in order to be chosen to their work ergonomics project. The garment was tested both at open air wintertime environment as well as indoors at office/warehouse-building. The test measurements showed that the variations in muscular loading were recorded without any adverse effect or limitations to the mobility of the person during his/her tasks. As result of the evaluation the EMG garment technology was accepted to be used in the study and a set of special type EMG garments was designed and tailored according to the needs of the research project.

Based on the comments from the researchers mentioned above and on our own experiences we have been able to define some basic EMG garment models available for limited production. Depending on the application we can now choose correct electrode materials, proper cloth fabrics, cutting and sewing methods etc. Also specifications and limitations for daily use, durability and instructions for handling, cleaning and washing have been formulated. However several issues have been noticed for future development to meet more general measurement demands. We must explore the specific factors that effect to the correct sizing of garments. Also there is clear need to define in more detail how to maintain sufficient flexibility and stretching of the cloths while at the same time keeping reliable contact between the electrodes and the skin. For individuals having anatomical deviations compared to normal population, certain adjustment may be necessary to be developed into the garments. Anyway the experiences so far encourage us to believe on the future of EMG garments in specific scientific and rehabilitation purposes and later on even in mass production quantities for consumers.

3 Research of the contactless textile EMG sensors integrated into the garments

3.1 *Development of the ConText prototypes*

In January 2006, ConText project started with the aim to develop a wearable system to measure user's muscular activity and stress. This system will be made of new contactless EMG sensors integrated to textile materials. Hence, one target of the project is to develop new EMG electrodes, which work with the capacitive principle and can measure also through a textile layer without the direct electrical skin contact. Several technologies are under investigation for the integration of the sensors into textile materials. These technologies are embroidering, printing, weaving, and laminating. In addition, studies to integrate data and power lines to textile materials are done during the project. Besides the design of the new sensor technology, the project aims to develop an algorithm to translate the raw EMG signal into information of the muscular activity and stress state of the test person. Technologies under development will be tested in a form of the feasibility prototype, which will be a tool to prevent musculoskeletal disorders. Research activities include also trials towards the best design for the prototype vest, and concept development for the new technology as well as forming of the application forum to collect feedback from the specialists and potentials users. [3]

Project is progressing well in all the areas. Development and testing of the sensors has confirmed the use of contactless sensors for EMG measuring even through a textile layer. [4] Integration of the sensors into the textiles has succeed very well with all the tested technologies [5], and this work will be continued. Research for the algorithm to monitor muscle activity and stress state to prevent exposure to musculoskeletal disorders is in progress [6], but it is too early to speak about the stress test results yet. During the first year, ConText group also wanted to study the misalignment issues in order to find out the usability level of the ConText vest, when there is no fixed skin contact during the measuring. In the circumstances, ConText technology enables even higher level of user comfortability as the sensors do not require direct skin contact e.g. a EMG vest can be used upon the user's own shirt. Figure 3. shows the recent prototype of the ConText vest.

Figure 3. *Researcher from the TNO is wearing the ConText prototype vest and taking turns of resting and 90 degress abductions with her arms.*

3.2 *Testing*

The use of contactless sensors incorporated in textile adds new problems in the design of the prototype shirt. The contactless sensor is not fixed to the muscle, which could lead to a misalignment between the sensor and the desired muscle due to movement of the shirt with respect to the body. Useing a tracking system, the displacement of the shirt, relative to the m. Trapezius pars descendens during movement was recorded. On anatomical positions of the body (vertebra C7 and the acromion), markers were placed at reference positions. On the reference position on the shirt (the middle between the anatomical points vertebra C7 and acromion), another marker was placed. During movements (elevation, abduction and anteflexion of the shoulder), the position of the markers were tracked.

3.3 *Results*

To analyse the results, the measured position of the sensor-markers is compared with the reference position according to SENIAM [7]. On Figure 4, the relative displacement of the shirt compared with the reference position is shown. We see displacements up to 1 cm towards the acromion and 1 cm up to vertebra C7 along the x-axis. In the y-axis, we see a shift from -2.5 cm to 1 cm compared with the reference. The results for the left shoulder are analogue.

To investigate the acceptance of this displacement, we measured the muscle activity of the trapezius muscle at 5 positions: the reference position (SENIAM) and at 2,5cm and 5cm towards the spine and towards the acromion. The amplitude and frequency content for the left and right trapezius muscle are compared. The frequency response for every measurement is similar compared with the SENIAM reference. The Figure 5. shows the amplitude characteristic of the muscle activity during movement. Towards the spine, the variability of the amplitude is rather low, whether towards the acromion, there is a high variability. If the displacement is within 2,5cm, the signals are acceptable.

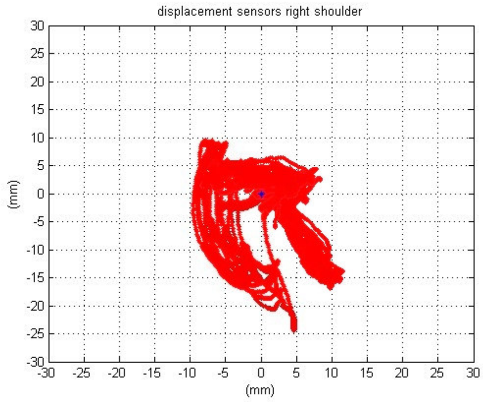

Figure 4. Displacement of the right shoulder

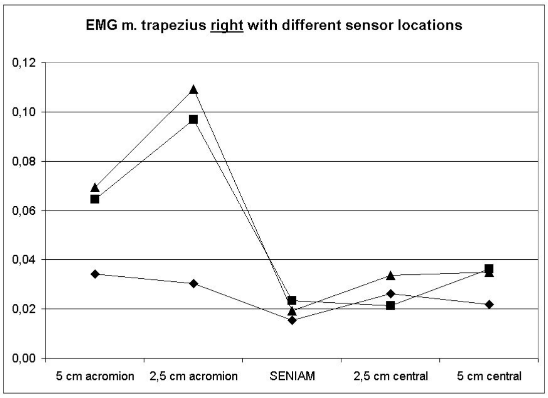

Figure 5. Amplitude of muscle activity of the m. Trapezius right measured at 5 different positions during movement: anteflexion of the arm (●), abduction of the arm (■) and elevation of the shoulder (▲)

4 Summary

According to the trials and studies with the EMG garments provide a real alternative to the traditional method using Ag/AgCl electrodes, especially in measurements, where heavy motions are present, or when the longterm measurements are useful. The EMG garments have also showed their user friendliness in the field experiments as e.g. the time consuming placing of the electrodes can be avoided, and when the traditional method is impractical to be used. ConText project is aiming towards the final feasible prototype, which will be a vest with the textile integrated sEMG sensors and electronics to measure user's muscle activity and stress state on the comfortable and unobtrusive way. This far the results have been very promising . Project will last until June 2008.

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