CONTACTLESS EMG SENSORS FOR CONTINUOUS MONITORING OF MUSCLE ACTIVITY TO PREVENT MUSCULOSKELETAL DISORDERS

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Abstract

The aim of the ConText project is to develop a wearable textile with integrated EMG (electromyography) sensors capable of measuring muscle activity in an unobtrusive way. This intelligent vest can be used as a biofeedback system in order to give the user information about muscle fatigue or muscle tension due to stress. This tool can be used in health care, for instance for prevention of musculoskeletal disorders, revalidation and sports.

1 Musculoskeletal disorders (MSD)

MSD occur when there is a mismatch between the physical requirements and the physical capacity of the human body. The term MSD refers to a group of disorders with similar characteristics (myalgia, tendonitis…) [1].

MSD are caused by a combination of factors such as repetitive motion, force exertion, psychological and physiological stress, vibration and bad posture. For example, high physical and mental job demands can cause work-related musculoskeletal disorders (WMSD). WMSD have both personal consequences, such as discomfort, pain, malfunctioning and disability, and socio-economical consequences such as reduced productivity, reduced performance and absenteeism [2]. Forty to fifty percent of all work-related absences are affected by WMSD. This problem leads to losses of 0.5 to 2% of GNP per year. The problem is noticed by the European Commission and reported in two memo's [3,4]. The EU Advisory Committee on Safety, Hygiene and Health at work emphasizes that a number of measures should be taken to enable successful prevention of WMSD.

A tool to measure the pathomechanisms of MSD could be very useful. Wearable electronics can assist appropriate medical management by early diagnosis of symptoms and detection of MSD for enabling prompt treatment and proper rehabilitation.

2 The ConText EU-project

Clothes are omnipresent in our daily life. Bringing the measurement equipment and electronics in daily life could be beneficial, so the acceptance threshold for continuous monitoring can be lowered. The European project, ConText [5-7], proposes a wearable tool for continuous monitoring of sEMG with contactless sensors incorporated in textiles. The consortium exists of Philips Research (The Netherlands), TNO (The Netherlands), Clothing+ (Finland), TITV (Germany), TU Berlin (Germany) and KU Leuven (Belgium).

This proposed system can give specific feedback about increasing muscle activity and stress levels to workers at risk and/or patients suffering from WMSD.

2.1 Data interpretation

The KU Leuven focuses on developing algorithms to detect psychophysiological stress in critical situations. By means of a simulation of repetitive chain work and office work, we will study the impact of psychophysiological stress on muscle activity, for example of the M. trapezius.

Electromyography (EMG)

The information about the muscle activity is retrieved from the sEMG. The sEMG records the electrophysiological signal of the muscle. Nerve cells and muscle fibres are depolarized when activated by a certain threshold voltage. The result is the propagation of a depolarization wave along the nerve and muscle fibre. This electrical wave is the direct cause of muscular contraction. A muscle exists of several motor units, a unit of one nerve and the corresponding muscle fibres. The measured sEMG is the sum of the depolarisation waves of several motor units in the environment of the electrode [8].

Stress algorithm

The scope of the ConText project is to investigate the influences of fatigue and stress on muscle activity. The human body is experiencing stress, whether this stress is pure physiological or psychophysiological, as a threatening situation. A strong hormonal reaction is invoked: the level of cortisol and norepinephrine in the body is augmented. This increase from the stress hormones brings the body in a condition with increased alertness where the surviving instinct of the body is augmented: increased heart rate, increased blood pressure, increased muscle tension, ... This reaction is the so-called 'fight or flight'-reaction of the body [9]. The secondary needs (emotions, thinking …) are turned off by the body as they are not needed. Recent research did establish a relationship between stress and increase in muscle activity.

It has been shown by Westgaard et al [10] that an additional complex mental task to a postural load increases the muscle activity significantly in the M. Trapezius pars ascendens. However it is difficult to distinguish the muscle activity from postural load and the increased muscle activity from stress. Interpretation of EMG may be assisted by electrocardiography (ECG) signals and the output of accelerometers.

The development of this stress algorithm would enable a bio-feedback signal that allows the reduction stress (at work or in other applications like sports, revalidation,…) specifically or WMSD in general.

2.2 Technology

In the project, the sEMG is measured by a wearable system for continuous monitoring. Therefore a high level of electronic integration in textiles is needed, so the user is no longer hindered by being monitored.

In the ConText project two technology innovations are developed to increase the comfort of wearing. First, instead of conventional contact electrodes, capacitively coupled contactless sensors are developed. The second key technology of the project is the integration of the electronics into textiles. To this end, electrodes and signal wires are made using weaving or embroidery techniques of conductive threads and printing technology on textiles.

Contactless sensors

The traditional contact electrodes are not very useful for textile integration: good skin contact with conductive gel is needed for this type of electrodes. In the literature [11-13], contactless sensors for ECG are proposed. These sensors detect an electric displacement current by means of a capacitive coupling to the body instead of detecting a Nernstian current; therefore, they require no electrical contact with the skin. The avoidance of direct skin contact gives the opportunity to wear the vest above other clothing. The contactless sensors consist of a conducting plate covered by an insulating layer, forming a parallel plate capacitor with the skin [14].

A typical setup for measuring sEMG is a bipolar setup. Because of the capacitive coupling, the impedance of the electrode is very high. Therefore an impedance converter is placed directly on top of the electrode. An extra reference electrode is also used to reduce environmental noise.

The first results of tests with the contactless sensors are promising. Figure 1 shows the frequency spectrum of sEMG of the M. Biceps Brachii measured with contactless and with contact electrodes in rest and in contraction. In contraction, the contactless sensor shows the same characteristics as the contact electrode. In rest however, the level of the measurement with the contactless sensor is about 20dBV higher than with the traditional contact electrode. This indicates a lower signal-to-noise ratio for the newly developed sensors. It must be mentioned that it is not possible to do the two measurements at the same time on the same position.

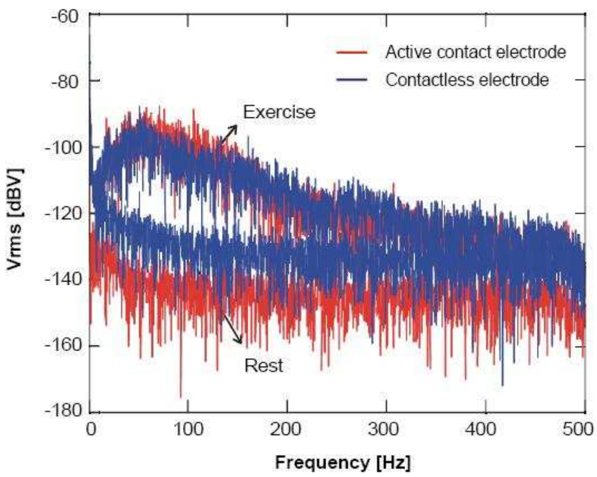

Fig 1: spectra of the sEMG measured with both the contactless sensor and the traditional active contact sensor (Philips Research).

Although the first results are very promising, there is a small degradation in robustness for motion artefacts.

In the prototype vest, the contactless sensors are developed on flexible PCBs. Research is needed to determine the best position for the sensors according to the needs described in 2.1. In a future stage of the project, the sensors (together with the electronics) will be integrated in textile.

Integration in textiles

A next step is a high level of integration in textile. Not only the conductive yarns need to be integrated, also the sensors and the electronics have to be integrated. Several new technologies are explored by the project.

New conductive threads are being developed for weaving data wires and power lines in the clothing. Another idea which is investigated is printing with conductive material on the textile.

For the integration of the sensors, embroidery with conductive and insulated threads is used. A prototype is shown in figure 2. The first measurements with this prototype are promising.

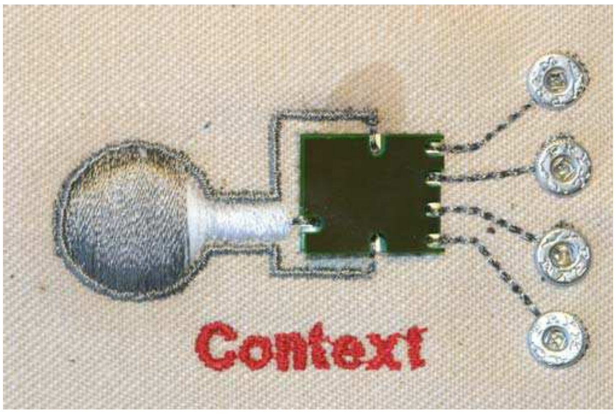

Fig 2: prototype of an embroidered sensor [15].

The design of a contactless sensor and the technology for integration of electronics in textile allows the user to wear this equipment as comfortable clothing. The acceptance threshold for monitoring equipment in our daily lives can be lowered by merging the electronics into our environment. This brings professional myographic methods to the home or work situation for use by untrained individuals without intervention of a medical expert. It will bring professional measurement technology to the consumer and opens new user scenarios for health monitoring, sports training and self-awareness applications. A first application, here presented and described in the paper is stress-monitoring for the reduction of WMSD.

3 Conclusion

WMSD is a highly rated problem in society. An important factor in the development of WMSD is stress. This project describes a tool for health monitoring with intelligent clothing. It could be demonstrated that the contactless sensors deliver similar signals as contact electrodes, although the signal-to-noise ratio is still lower than the nowadays used active contact electrodes. The development of conductive threads and printing technology with conductive ink offers the possibility for high level integration of electronics and sensors (by embroidery) in clothes. This project is a result of the tendency of health care nowadays: by offering professional intervention for every problem, we are moving to a situation of self-assessment with personal risk management. This vest is an application for self-assessment of stress to prevent WMSD.

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