

EUROPEAN COMMUNITY PROJECTS ON SURFACE ELECTROMYOGRAPHY

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Abstract - Three European Projects dealing with Surface Electromyography (SEMG) are presented. *Surface EMG for Non-Invasive Assessment of Muscles (SENIAM, 1996-2000)* produced a set of European guidelines concerning EMG sensors, their positioning criteria, EMG processing, modeling and information extraction. *Prevention of muscle disorders in operation of computer input devices (PROCID, 1998-2001)* dealt with wire and surface EMG and provided insight in muscular disorders in computer users. *Neuromuscular assessment in the Elderly Worker (NEW, 2001-2004)* will apply SEMG techniques to the assessment of aging individuals performing repetitive or straining work. SEMG techniques are not meant to replace needle techniques. They provide a different kind of information which is valuable in many applications concerning ergonomics, rehabilitation, occupational, sport and geriatric medicine.

Keywords - electromyography, surface EMG, fine wire EMG, needle EMG, muscles, European Union

I. INTRODUCTION

Surface Electromyography (SEMG) has come to maturity during the last two decades. The specific applications of needle, wire, and surface techniques have been described in books and review articles. Ample references are provided in a comprehensive review by De Luca [1]. Despite the amount of literature in the field, the many tutorials available in the web and the specific journals (such as the Journal of Electromyography and Kinesiology), confusion still exists with regard to the specific fields of applications of the different EMG methodologies. In general, technology assessment studies have examined SEMG in the light of (or with respect to) traditional needle-EMG diagnostic techniques. The conclusions of Haig et al. [2] are: "There are no clinical indications for the use of SEMG in the diagnosis and treatment of disorders of nerve and muscle". The conclusions of Pullman et al. [3] are "SEMG is considered unacceptable as a clinical tool in the diagnosis of neuromuscular disease at this time." and "SEMG is considered an acceptable tool for kinesiologic analysis of movement disorders,.... for evaluating gait and posture disturbances,....".

While these statements, at this time, are correct, they do not provide the complete picture. For example, it is true that "Resting state information and insertional activity are important in the characterization of various myotonic disorders. They have not been detected by any SEMG methodology." [2], but it is also true that localization of innervation zones, estimation of muscle fiber conduction velocity, identification of fatigue indexes and of activation intervals are much easier with surface techniques than with needles. Since they have rarely been attempted with needle techniques and their clinical relevance has not yet been

satisfactorily assessed, they were not used as grounds for comparison in the above mentioned papers. It is however unquestionable that literature on SEMG has, in general, been quite poor and the lack of a standard methodology has plagued the field and greatly hindered the quality of the research and its clinical applications. This fact has motivated a number of important developments in the last few years.

The development of SEMG in the last few years is highlighted by the events listed below:

1. **The increasing interest of scientific journals on EMG.** Medical Engineering and Physics recently published a special issue (n. 6 and 7, 1999) on the topic. A special issue of the Journal of Electromyography and Kinesiology (October 2000) was recently devoted to SEMG. Many articles related to this topic have been published on engineering as well as life sciences journals. Dozens of web sites have been created and multimedia teaching tools have been developed.
2. **The approval of concerted actions and shared cost projects by the European Union.** A concerted action (c.a.) on *Surface EMG for Non-Invasive Assessment of Muscles (SENIAM)* was funded by the European Commission in the 1996-2000 period. The aim of concerted actions is to enhance international cooperation in a given field of interest. The fact that the EU decided to fund this c.a., which is focused on recommendations and proposition of standards, should be regarded as an important acknowledgement of the maturity and potential benefits of SEMG. A second c.a. on *Prevention of neuromuscular disorders in the use of computer input devices (PROCID)* has been funded by the European Commission for the period 1998 -2001. Although this project was not originally focused on development or standardization of SEMG, it is largely based on the EMG technique and opens up interesting applications for SEMG. A shared cost project on *Neuro-muscular assessment of the Elderly Worker (NEW)* was recently approved and will develop over the next three years. This project will apply non invasive electromyographic and mechanomyographic techniques to the study of work and age related neuromuscular problems.
3. **The growing number of European products** that acquire, store and process surface EMG not only for the traditional applications in biofeedback or gait analysis but also for applications in neurology, ergonomics, occupational health studies, neuro-rehabilitation, motor rehabilitation, exercise physiology.

II. THE SENIAM CONCERTED ACTION

The SENIAM c.a. involved 16 European partners but was

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managed by five main groups and coordinated by Dr. H. Hermens (h.hermens@rrd.nl), Roessingh Research and Development, Enschede, The Netherlands. It produced seven volumes and a CD-ROM on the topic and a summary book of European Recommendations [4], recently translated in Italian and used as textbook in a set of dissemination activities and courses.

The first objective of the SENIAM c.a. was the assessment of the state of the art and the exchange of knowledge and experience among different European Labs. A large number of publications concerning SEMG (144) which appeared in seven Journals between 1992 and 1996 were read and analyzed. They concerned 53 muscles and 353 electrode placements. In 58 (16%) of such placements the location of the electrodes on the muscle was not indicated and in many of the remaining cases it was incorrect. An astonishing variety of descriptions of electrode locations was identified (e.g. 21 on the biceps brachii, 26 on the tibialis anterior, etc) that could be classified in the following four categories: over the muscle belly, over the motor point, at a fixed distance from an anatomical reference, between the motor point and the distal tendon. Considering the variety of electrode sizes and interelectrode distances it is difficult to find two authors who detected EMG in the same way from the same muscle. The conclusions reached in [2] and [3] are therefore not arbitrary and in great part explained by this lack of scientific approach to the issue of EMG detection.

The second objective of SENIAM was to correct these situations by generating consensus about a set of recommendations that are now available and published in the SENIAM books [4]. This process of generating consensus has been carried out in a number of consecutive steps, with the continuous involvement of many experts in the field. After having obtained the state of the art on actual use of SEMG sensors (the configuration of electrodes) and sensor placement procedures in the European labs, a special workshop was organized to obtain a good understanding of the present knowledge of the relevance of the sensor and sensor placement properties with respect to the SEMG signal characteristics. This workshop resulted in a first set of recommendations that were open for discussion to all members of the SENIAM club (over 100 members). Based on their feedback, consensus was obtained on a set of recommendations for sensor properties and sensor placement procedures. As an example; on long muscles electrodes should have a diameter smaller than 10 mm, should be spaced by less than 20 mm and should be positioned midway between a tendon and the innervation zone closest to that tendon. Smaller electrode sizes and interelectrode distances should, of course, be adopted on small/short muscles. Identification of the innervation zone may be performed using an electrode array.

The third objective was to reach consensus and provide Recommendations about the signal processing methodology for estimation of amplitude variables, spectral variables and muscle fiber conduction velocity in a wide range of applications, involving neurology, movement analysis and

long-term recordings as being used in occupational health studies. A distinction was made between signal processing

methods with a "proven" clinical value and new upcoming methods. Only for the first category recommendations were made, mostly concerning assessment of myoelectric manifestations of muscle fatigue.

The fourth objective was to select a number of SEMG generation and interpretation models and make them available to students and to the clinical community. Four models were selected. They are all available on the SENIAM CD-ROM and provide an important tool for understanding these signals. Teaching tools for physical therapist, exercise have also been developed and are available upon request.

In addition, guidelines for reporting EMG data and a list of over 150 SENIAM publications are available in [4].

III. THE PROCID CONCERTED ACTION

High prevalence of musculoskeletal disorders is reported in relation to computer work. The low force requirements during intense computer work may cause subliminal physiological effects on the sensory system preventing perception of fatigue. This may cause overloading of the system and irritation of some MUs with consequent pain. The hypothesis is that these overloaded MUs are always the same during a repeated action ("Cinderella Theory" proposed by G. Hägg).

The *Prevention of neuromuscular disorders in the use of computer input devices (PROCID)* c.a. involved 10 European partners and was coordinated by Dr. R. Kadefors, (roland.kadefors@niwl.se), National Institute for Working Life, Goteborg, Sweden. The aim of the project was the investigation of the physiopathological basis of work related muscular disorders among computer users. The project focused on a) development of intramuscular (fine wires) measurement techniques suitable for mapping motor unit (MU) recruitment, b) development and evaluation of signal processing algorithms for identification of single motor unit action potentials (MUAP), c) evaluation of MU recruitment, d) evaluation of stress induced muscular strain at the MU level, e) formulation of recommendations.

The research carried out in this project demonstrated the importance of motor unit firing patterns for development of muscular pain and provided additional evidence for the "Cinderella" theory proposed by G. Hägg. In order to give this knowledge clinical impact and applications, it is essential that EMG techniques be developed for characterization of motor-unit recruitment, firing statistics and recovery using surface arrays. Although most of the work in this project involved the use of fine wire electrodes, some information may now (or in the near future) be detectable with surface arrays.

The results of this concerted action are summarized in a number of papers published in two special issues of the European J. of Applied Physiology (vol 83, n. 2-3, October 2000) and the J. of Electromyography and Kinesiology (Vol 11, May 2001), as well as in the proceedings of two scientific meetings [5,6]. SENIAM and PROCID provided a solid basis for the NEW shared cost project proposed in March 2000.

IV. THE NEW SHARED COST PROJECT

The fraction of people older than 60 that are still working in the EC is now 22% and is expected to grow to 30% by 2025. As life expectancy and retirement age increase, health statistics indicate an increased incidence of work related neuro-muscular disorders and a need to study them. The information contained in the electrical and mechanical signals generated by muscles of the hand, wrist, arm, neck and shoulder regions will provide means for addressing the problem.

The European project *Neuromuscular assessment in the Elderly Worker (NEW, 2001-2004)* will address this problem with a consortium of nine partners coordinated by Prof. R. Merletti, (merletti@polito.it) of Politecnico di Torino, Torino, Italy. The project relies extensively on the results of the two previous concerted actions SENIAM and PROCID which played an important role in identifying the problem, proposing an approach and establishing a partnership. The approach will focus on the non-invasive assessment of muscle properties through the information extracted from the electrical and mechanical signals generated by muscle contractions. These signals are referred to as surface electromyogram (SEMG) and mechanomyogram (MMG). The second describes the vibration of the skin due to the firing of the underlying MUs and contains information about their firing rate.

New SEMG and MMG detection systems, either separated or combined, will be developed and applied in static and dynamic conditions both in laboratory and field situations. An atlas of muscles suitable for examination by means of these techniques will be prepared. A data logger will be developed for long term recording of signals in the field. Advanced processing systems for information extraction from SEMG and MMG will be developed and applied to signals recorded in laboratory or field situations. Such information will be correlated to the working conditions and particular activities and or symptoms of the investigated subjects who will include workers performing repetitive or straining activities such as nurses, computer operators, cashiers, assembly line workers, and others.

It is expected that the results will provide insight on the Cumulative Trauma Disorders (CTD) and Repeated Strain Injuries (RSI) mechanisms and on the possibilities of their prevention.

V. FALL-OUTS AND SPIN-OFFS

SEMG based information is relevant in many fields such as evidence-based rehabilitation, sport and space medicine which are benefiting from the EU sponsored work. Consider, as an examples, the need to monitor the effect of a neuromuscular rehabilitation treatment, the effect of microgravity or aging or sport training. In these and many other situations SEMG techniques turn out to be useful and are producing industrial spin-offs involving small companies. Dissemination of the results will hopefully increase the quality of university training of health operators active in these

fields.

The extraction of relevant information from the raw signals detected on the muscles requires a variety of different competencies that are not available in any single European laboratory and range from neurophysiopathology to ergonomics, occupational medicine, electronics, signal processing and computer science. The need to look for partners at the European level facilitates exchange, cross-fertilization and standardization, avoids duplication of efforts and strengthens European science.

Economic and health related perspectives are conditioned by the clinical awareness of the capabilities offered by the new techniques. For this reason, continuing education and training initiatives are planned at many levels including Universities, Schools for physical therapists, ergonomists, sport trainers. In addition to the SENIAM and PROCID books and proceedings, contributions to encyclopedias and review papers on these topics have been published [7], [8], [9]. It is worth to note the translation into Italian of the SENIAM book about European Recommendations and the organization by the Regional Administration of Piemonte (Italy) of six courses attended by 400 medical doctors and physical therapists.

VI. FUTURE PERSPECTIVES

The development of selective linear and bidimensional electrode arrays opens up new opportunities in the field of SEMG and may induce clinicians to think that this technique will eventually replace needle EMG. This will probably never be the case. The worlds of surface and needle EMG are very different and well separated and will probably develop independently towards different goals and for different applications. One of the future goals of SEMG research is the identification of anatomical, physiological and histological properties of the most superficial MUs, such as individual MU length and innervation zone location, conduction velocity estimation, firing instants, fatigue characteristics and, possibly, fiber type. Relevance of this information will probably lie more in rehabilitation, sport and occupational medicine rather than in neurological diagnosis.

VII. CONCLUSIONS

The SEMG techniques have gained recognition and acceptance in recent years. Recent European Union Concerted Actions and Shared Cost Projects have supported research in the field of SEMG with positive results. The technique should not be seen as an alternative to needle EMG since it has different applications. As a consequence it should not be evaluated using needle EMG as a golden standard, unless the opposite is done as well. An effort should be undertaken by Scientific Societies, Health Management Organizations and Schools of Medicine to disseminate the acquired knowledge which should become part of the training of rehabilitation, occupational and sport specialists.

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