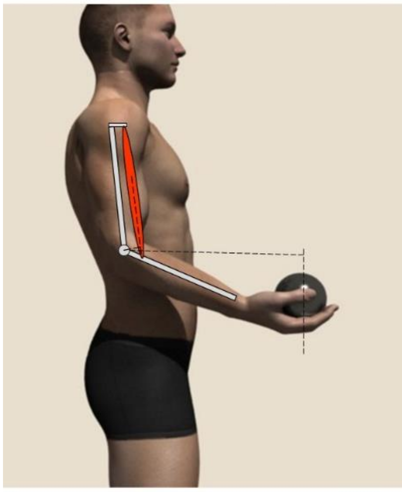
Movement control and non-invasive electromyography: development of models and clinical teaching tools (CoMES)



1. Introduction to CoMES Teaching Material.
A work in progress.

Rehabilitation medicine and physiotherapy are undergoing a major technological revolution that is deeply affecting clinical practice and research as well as the role and the training of physical therapists.

This revolution largely involves rehabilitation technology, robotics and engineering and is progressing faster in some countries than in others, depending on the motivation, attitude, level and quality of education of the operators in the field (physiotherapists and occupational therapists, kinesiologists, movement scientists, etc). Since the technology largely concerns assessment of results and outcome, the impact on Evidence Based Rehabilitation (EBR) is very relevant.

One aspect of this revolution concerns the use, understanding, application and interpretation of biomechanical and surface electromyography (sEMG) information. Progress has been particularly fast in these areas because of the activities of the International Society of Biomechanics (ISB), the International Society of Electrophysiology and Kinesiology (ISEK) and the many institutions engaged in rehabilitation science and robotics. Project CoMES aims to limit the widening gap between technological advances and clinical education by providing teaching material designed for clinical operators.

2. Objectives

Biomechanics and muscle electrophysiology are two fundamental pillars of training in modern prevention and rehabilitation sciences. The greatest potential for clinical and technological progress is with the involvement of clinicians having a uniform solid background in the techniques and terminology across countries. This will facilitate the translation of research laboratory advances into clinical practice, and feedback from clinical experience, into our deeper understanding of pathological conditions of the nervous and musculoskeletal systems.

This project focuses on the preparation of on-line teaching material designed for, and in cooperation with, physiotherapists and movement scientists. It relies heavily, but not exclusively, on research carried out at the Laboratory of Engineering of the Neuromuscular System (LISiN, Politecnico di Torino) and supported by a number of EU projects and grants from two Bank Foundations (Compagnia di San Paolo and Fondazione CRT) in Torino, Italy.

Our first step is to provide a set of 10 simple and basic modules implemented in Power Point, make them freely available and downloadable from a number of websites, and collect feedback from students and teachers. The current version is primarily aimed to teachers of physiotherapy schools (BS level).

Our second step will be to add a narrating voice and interactive exchanges, exercises, and forms of self-assessment, directly accessible and usable through the web as e-learning and continuing education for students, teachers and professional operators.

Our third step will be to add more applications, in-depth material and new topics such as mechanomyogram, electrically elicited sEMG, clinical applications of sEMG decomposition, etc.

The list and a short description of the 10 modules, implemented in step 1, follows below.

3. Outline of the structure of the teaching material.

About 30-70 slides/animations in each of the 10 modules.

1. **Physics of mechanical phenomena.**
2. **Basic Biomechanics.**
3. **Physics of elementary electric phenomena of relevance for understanding surface EMG.**
4. **Elementary analysis of bioelectric signals.**
5. **Basic neuromuscular electrophysiology and mechanisms of sEMG generation.**
6. **Surface EMG detection: configurations, criteria, common mistakes.**
7. **Features of sEMG**
8. **European recommendations and their updating**
9. **Mathematical models and computer simulations of sEMG**
10. **Examples of recording and interpretation of sEMG**

The first three modules provide a review of basic concepts to establish a common starting point among users of different background, coming from different schools and countries.

4. The challenge

Among the many branches of medicine, rehabilitation is likely the one with the strongest interaction with physics and engineering. Rehabilitation sciences involve mechanical, electronic, robotic, material and signal processing technology and engineering. New professions are emerging with a strong engineering imprint while the old professions are changing under the pressure of modern and powerful

Surface electromyography is for the physiotherapists dealing with muscles what electrocardiography is for the heart and the cardiologist, or electroencephalography is for the brain and the neurologists.
While clinical ECG and EEG applications go back many decades, sEMG has been lagging and is still in the early phase of transfer from research labs to education, training and clinical practice, with large differences from country to contry.

The information provided by sEMG is extensive and concerns both the muscle and the CNS controlling strategies. The extraction and interpretation of this information from the sEMG signals and images is more complex than for ECG and EEG but most technical problems have been solved. Surface EMG is vulnerable to misinterpretation and misuse and requires considerable competence by its user. Such competence is not widely available today, despite the many books and articles published in the field.

The challenge of the CoMES Project is to facilitate the acquisition of this basic competence by the operators of the field across countries and schools, using internet.

New teaching approaches are required for this purpose, as indicated by the experiences of the Schools of Physiotherapy in Australia, Canada, USA, Central and Northern Europe.

5. Applications

Like ECG and EEG, sEMG is not a therapy (with a few exceptions). Rather, is a technique for prevention of disorders and for monitoring the effectiveness of treatment, training and interventions, as well as for the control of rehabilitation equipment, exoskeletons and prosthesis.
The development of advanced sEMG technology, often combined with stereophotogrammetry and/or inertial measurement units (IMU), has widely extended the applications in a variety of fields ranging from occupational and sport medicine, to rehabilitation medicine, to preventive medicine, to the investigation of pathophysiology of movement control in healthy or elderly subjects and patients, to obstetrics.

Visualization and documentation of kinematic and electrophysiological variables by means of IMU and High Density sEMG (HDsEMG or sEMG imaging) provides clinicians with powerful tools for the understanding and measurements of movement control disorders, for the assessment of outcome, especially in case of questionable or controversial therapies, and for Evidence Based Rehabilitation.
Insight into the technology, limitations, sources of errors and improper use of these tools is a fundamental requirement for sport and exercise physiologists, movements scientists, physiotherapists and rehabilitation operators. Rehabilitation technology will impact more and more on clinical procedures and on their assessment as well as on the future of professionals being trained today.

Decomposition of the sEMG into the constituent motor unit action potential trains is opening up an important window on the control strategies of the CNS. The measurement of spectral features and muscle fiber conduction velocity is providing information on peripheral processes.
EMG imaging will likely make available new biofeedback techniques and rehabilitation games will help in recovering lost abilities. The solution of the crosstalk problem will sharpen the monitoring of muscle coordination. These tools will provide a more rigorous approach to the assessment of effectiveness of treatments, reducing the social costs of rehabilitation and the impact and cost of therapies of questionable effectiveness. The training of operators able to use these tools properly in under way in many countries.

6. Application examples

Foot eversion effort Foot dorsiflexion effort

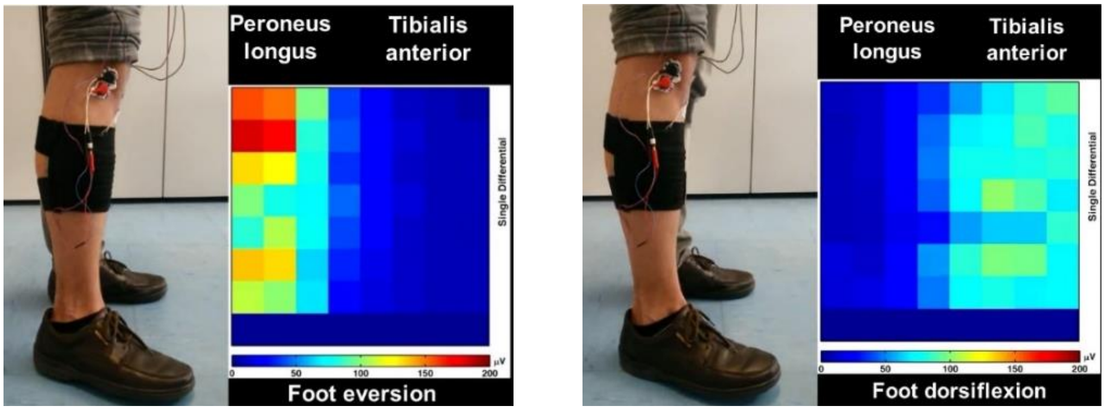


Fig. 1. Surface EMG maps associated to eversion and dorsiflexion of the foot. Longitudinal differential detection. Electrode grid of 8x8 contacts with 10 mm inter-electrode distance applied to the tibialis anterior and peroneus longus muscles. See video on www.robertomerletti.it ->Teaching material (clinical) -> Videos -> N.14.

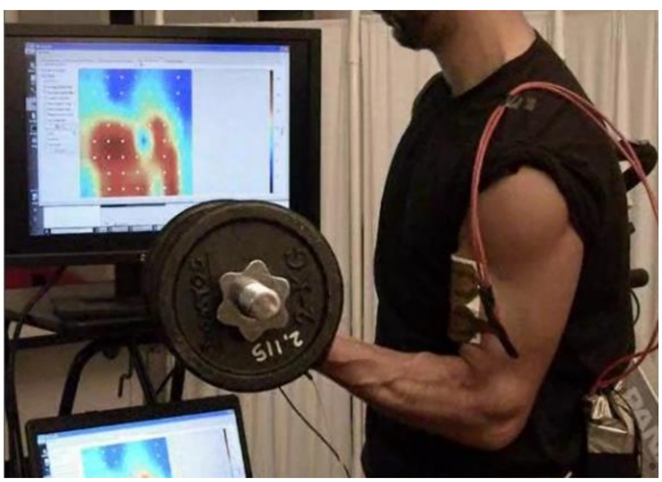


Fig. 2. Activation of the biceps brachii during a concentric contraction. The short and long head of the biceps can be distinguished on the computer screen.
Longitudinal differential detection.
Electrode grid of 8x8 electrodes with inter-electrode distance of 10mm.
See video on www.robertomerletti.it ->Teaching material(clinical) -> Videos-> N.21.

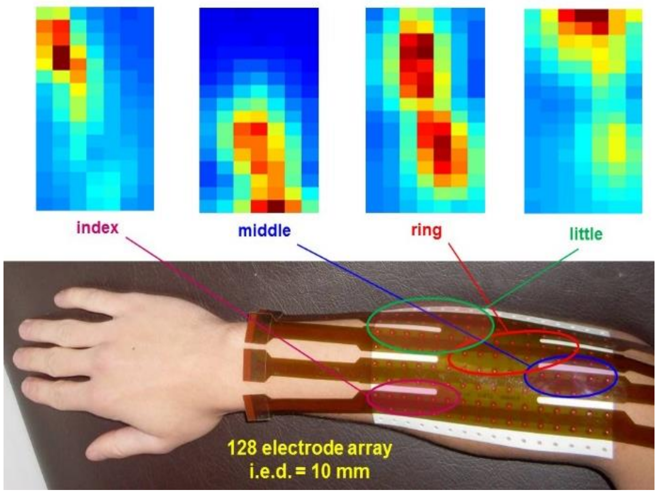


Fig. 3. Surface EMG maps associated to the extension of the individual fingers. Longitudinal differential detection. Electrode grid of 16x8 contacts with inter-electrode distance of 10mm.
See video on www.robertomerletti.it ->Teaching material (clinical) -> Videos -> N.11.

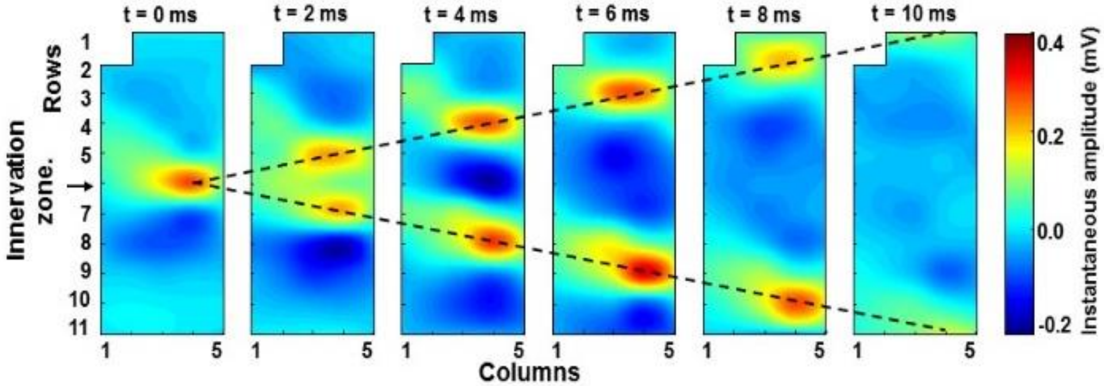


Fig. 4. Propagation of a motor unit action potential under an electrode grid on the biceps brachii. Longitudinal differential detection. Electrode array of 12 rows by 5 columns.
Interelectrode distance = 8 mm. Instantaneous interpolated images.

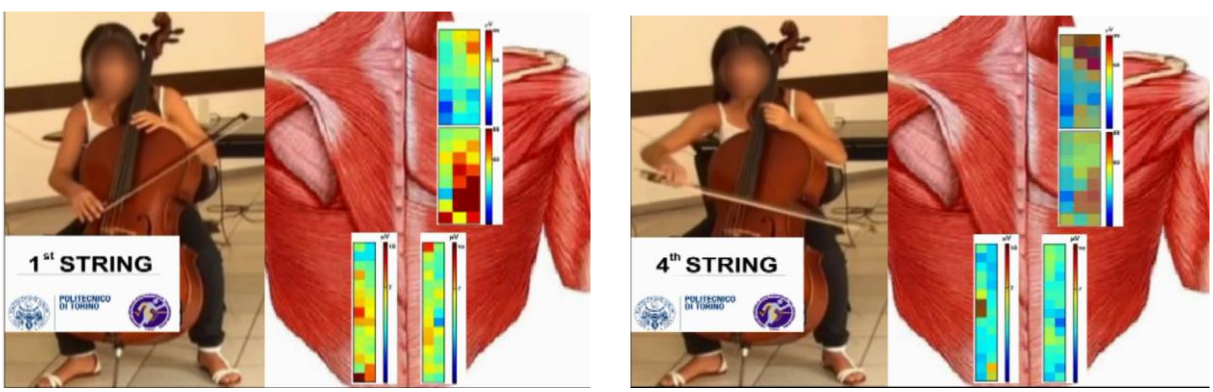


Fig. 5. Surface EMG activity of the right trapezius and of the lumbar erector spinae in a cello player playing the first and the fourth string of the cello. Longitudinal differential detection. Electrode array of 12 rows by 5 columns. Interelectrode distance = 8 mm. The images represent the RMS of the sEMG of each pixel (electrode pair) computed on an epoch of 125 ms and provide information about the time evolution of the activity of the muscles under the electrode grids.
See related videos on www.robertomerletti.it ->Teaching material(clinical) -> Videos -> N.15-19.

Many other application examples deal with ergonomics and occupational medicine, space medicine, prevention of surgical and obstetric lesions, control of artificial limbs and external devices. Some additional examples are provided in *www.robertomerletti.it ->Teaching material(clinical) -> Videos*

7. Participating institutions

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