Commentaries about Project CoMES

February- March 2019

1	**Deborah Falla, PT, PhD**	Chair in Rehabilitation Science and Physiotherapy Director, Centre of Precision Rehabilitation for Spinal Pain (CPR Spine), School of Sport, Exercise and Rehabilitation Sciences, College of Life and Environmental Sciences,University of Birmingham, UK, www.birmingham.ac.uk/cpr-spine	
2	**Theresa Sukal-Moulton, PT, DPT, PhD**	Northwestern University Feinberg School of Medicine, Departments of Physical Therapy and Human Movement Sciences, and Pediatrics theresa-moulton@northwestern.edu	
3	**Roberto Gatti, PT, MSc**	School of Physiotherapy, Humanitas University, Milano, Italy, Physiotherapy Unit, Humanitas Hospital, Milano, Italy. roberto.gatti@hunimed.eu, roberto.gatti@sif-fisioterapia.it	
4	**Mauro Banfi, PT**	Physiotherapist and Osteopat, Lecturer at the Academia of Osteopathy (ASOMI), Torino, Italy atelierposturale@gmail.com	
5	**Catherine Disselhorst-Klug, PhD**	Head of the Department of Rehabilitation & Prevention Engineering, Institute of Applied Medical Engineering RWTH Aachen University, Germany www.rehabilitation-engineering.com	
6	**Usha Kuruganti, PhD**	Professor, Co-Director, Andrew and Marjorie McCain Human Performance Laboratory, Faculty of Kinesiology, University of New Brunswick, Fredericton, NB, E3B 5A3, Canada	
7	**Samuel D'emanuele MSc**	Kinesiologist, Graduate from the School of Exercise and Sport Sciences, University of Torino, Italy	
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Deborah Falla, PT, PhD

Chair in Rehabilitation Science and Physiotherapy
Director, Centre of Precision Rehabilitation for Spinal Pain (CPR Spine)
School of Sport, Exercise and Rehabilitation Sciences, College of Life and Environmental Sciences
University of Birmingham, UK
www.birmingham.ac.uk/cpr-spine

Although it is generally recognized that Physical and Rehabilitation Medicine and Physiotherapy are the branches of life sciences with the strongest interaction with physics and biomedical engineering, a wide gap remains between what is known and available from the research arena and what is taught in education programs and used in clinical practice.

Project CoMES made a remarkable effort to reduce this gap by generating a significant amount of on-line teaching material. The second half of the material is particularly oriented to teachers and to the students who wish to pursue teaching and research activities in their future. The material, which is arranged in 10 modules, has been prepared by three physiotherapists and by Prof. R. Merletti. This material commences with basic principles in physics (Modules 1, 2 and 3), introduces the basic concepts of biomedical signal processing and their applications to neuromuscular physiology (Modules 4 and 5) and describes the physiological meaning, the features and the clinical applications of surface electromyography (EMG) (Modules 6-10). This material is free to use and is intended to be made available in physiotherapy undergraduate and postgraduate programs for use by teachers and students.

The user of the 10 Modules is guided from the most elementary concepts of force and torque, velocity and acceleration, electric voltage, current and impedance, to the more sophisticated concepts of spectral analysis, myoelectric manifestations of fatigue, two-dimensional surface EMG amplitude maps and their interpretation. It is not expected that every physiotherapist is familiar with the technique of EMG, however, the number of physiotherapists working in clinical research laboratories, where this background is relevant, is rapidly increasing and is likely to be much more widespread in the coming years. In view of these developments, is important to provide every student with some background on this topic.

The most important message of this work is related to the notion of measurement in rehabilitation and the concept that surface EMG is to physiotherapy what ECG is to cardiology: that is, a tool for measuring progress and changes due to an intervention or associated to some condition. Physiotherapists must take part in the development of the many tools of their trade and this is a relevant example. Hopefully, the same approach will soon be applied to other techniques.

It is interesting to note that the content of the Final Report is not just a summary of the teaching material that is the main "product" of the Project. The report (only some parts are bilingual) is addressing the training of physiotherapists in Italy, the educational material provided by manufacturers, the main books and websites, the main review papers in the field and the encyclopedia items dealing with EMG. Finally, as indicated in the report, it is important that physiotherapists attend international interdisciplinary congresses and workshops since their role in rehabilitation engineering and technology should be greater than it is today.

Project CoMES is a significant contribution in this direction which hopefully marks the start of further efforts along the same line.

Theresa Sukal-Moulton, PT, DPT, PhD

Northwestern University Feinberg School of Medicine
Departments of Physical Therapy and Human Movement Sciences, and Pediatrics
theresa-moulton@northwestern.edu

It has been a pleasure to serve in an advisory role for the Project CoMES. The task that was undertaken was extensive in the range of topics that arecovered within 10 online modules. The end result is both comprehensive and understandable. The concepts are presented in a logical order and build upon one another from basic physics through application.

Although generally relevant to the profession of physical therapy, in personal experience these modules are relevant to my students in Northwestern University Doctor of Physical Therapy (DPT) program. Our DPT students get aspects of this information in different courses (for example, mechanics in kinesiology), but do not have the opportunity in school to apply surface electromyography (sEMG) to clinical or research situations. There is some exposure to scientific articles that utilize sEMG to form scientific conclusions, but unfortunately, the focus is far more on conclusions than critical evaluation of how those conclusions were reached. For the goal of passing the boards, focusing on the conclusions may be efficient – but our students also have the capacity and potential to extend far beyond this. These online modules are a great fit to build competency in sEMG in a systematic and approachable way. A particular strength of the modules is the opportunity to build common language and begin to filter out inappropriate usages of techniques and terms within this arena. PTs can build on this common language and knowledge of techniques to learn ways to evaluate and treat their patients with motor control challenges using sEMG in a reliable and consistent way.

The second step where voice over, exercises to confirm understanding, and self-assessment will be a positive addition to what is currently there. Some of the content is very detailed and many slides have a lot of information on them – so even for the most visual learners having a narration to help guide your eye and thinking about the material presented on the slides will improve comprehension, and therefore, application of these principles.

It's an exciting time for physical therapy, and these modules are a source of reputable continuing education in an accessible technology that stands to improve clinical care moving forward. It will be interesting to see the research questions that are answered using this training.

Roberto Gatti, PT, MSc

School of Physiotherapy, Humanitas University, Milano, Italy
Physiotherapy Unit, Humanitas Hospital, Milano, Italy
roberto.gatti@hunimed.eu, roberto.gatti@sif-fisioterapia.it

It is a pleasure to comment on the work of Prof. Roberto Merletti et al., relating to the Project CoMES. The ten online modules deal with those elements of mechanical and electronic physics necessary to introduce a student of physiotherapy to the world of instrumental analysis of movement, especially related to surface electromyography, thus somewhat reducing the gap between technological advances and clinical education.

Considering the experience of Prof. Merletti it is of no surprise that the material is presented in a logical order beginning with basic physics and concluding with instrumental applications.

I hope that the material created by Prof Merletti and his collaborators can be integrated into lectures given by teachers in kinesiology, biomechanics, electrophysiology, etc. in academic physiotherapy programs.

In my teachings of kinesiology (first year students) and kinesiology applied into clinical practice (second year students), I decided to integrate the contents of my teaching with some materials proposed by Project CoMES. For example, the module on *Basic biomechanics* is particularly rich of excellent iconography, and the module *Features and properties of the surface EMG signal* didactically presents concepts that are not simple to grasp.

However, to my mind, an important value of this work is the contribution it makes to help change the belief that physiotherapy can grow without taking into consideration technological progress. A mentality still held by many physiotherapists, especially in Italy.

This tendency may be due to two reasons. The first concerns a typical mindset (common in Italy) which promotes the corporative defence of a position more than collaboration among professionals, where the spread of technologies in clinical practice needs close collaboration among physicians, physiotherapists and rehabilitation engineers, still far from the common mindset.

The second reason is probably the most important and concerns a typical Italian issue: only a few Italian physiotherapy schools offer education in this field. One of the reason is that the management is often made up of teachers who have no specific competences and are not tuned with the scientific progresses in the physiotherapy field.

However, things are changing, the need for modern physiotherapy education is a need of contemporary society and the importance of an inter-professional approach to clinical practice is being recognized. In this direction, the material produced by Project CoMES may contribute to tuning physiotherapy education to the contents emerging from rehabilitation engineering.

Mauro Banfi, PT

Physiotherapist and Osteopat
Lecturer at the Academia of Osteopathy (ASOMI), Torino, Italy
atelierposturale@gmail.com

In the recent years, the development of microelectronic technology has greatly incremented the rate of development of devices for sEMG measurements, as well as the possibility of combined use of different and wearable equipment, opening up options for applications in a variety of fields.

Among these, the fields of rehabilitation and functional medicine should benefit from, and take advantage of, this fast expansion of knowledge, in an interdisciplinary context, in order to optimize treatment procedures, assess their effectiveness and reduce their cost.

This knowledge, whose relevance is largely underestimated in Italy, would generate applications of considerable impact for the National Health Delivery System.

It is well known that the training of Italian physiotherapists does not include any teaching in the field of sEMG nor it considers the interpretation of this signal in the assessment of rehabilitation and manual therapies.

There are almost no post-graduate or continuing education initiatives providing information and education about the state of the art of these non-invasive assessment tools and about the devices available on the market. Interdisciplinary study groups aiming at the investigation, development and use of these techniques, at the development of user-friendly software for clinicians, therapists and patients, are almost non-existent.

Rehabilitation and functional medicine have an immediate need for training operators in clinical research in this field in order to reduce the widening gap between technological developments and treatment/assessment procedures.

Like ECG and EEG, sEMG is a non-invasive powerful instrument providing real-time information during assessment as well as indices, computed off-line, to quantify changes do to interventions.

In many cases, it would be suitable for patient self-assessment by means of dedicated equipment, as is done for heart beat and blood pressure.

The basic objections concerning the use of sEMG are the lack of basic knowledge by the operators, the lack of interest leading to a limited market and consequent high equipment cost, complexity of the processing. The creation of interdisciplinary groups should overcome these difficulties and favor the development and dissemination of knowledge. For this reason, the material developed and made available within Project COMES can fill the basic knowledge gaps in physics, biomechanics and electrophysiology, up to the concepts of EMG signal acquisition with the most advanced sensor systems.

The COMES material is fundamental, not only as a teaching tool for learning about neuromuscular physiology and the properties of biomedical signals, but also as an intellectual stimulus toward the application of this knowledge in the fields of physiotherapy, functional medicine and manual therapy (osteopathy, chiropractic, ecc.).

It is highly desirable that this material becomes an integral part of the basic training of any rehabilitation operator as part of the academic curriculum, as well as of the post-degree continuing education. It is important to follow technology in real time and apply it as soon as possible thereby stimulating further developments and applications in the field.

These are some of the many applications of sEMG of relevance for physiotherapists:

1. Pre- and post-intervention assessments through the analysis of muscle electrophysiological parameters to quantify results.
2. Presentation in real time of sEMG features in biofeedback applications and rehabilitation games.
3. Assessment of the correct use of muscles and of their fatigue manifestations in diagnostic, preventive and occupational medicine, as well as in training and optimization of exercises.
4. Quantitative documentation of complex muscle activation patterns and strategies that today are assessed only visually. Managing negative compensations is a primary objective of both physiotherapist and manual therapists.
5. Control of orthosis and prosthesis that require highly trained personnel, advanced devices and assessment tools.
6. Validation and improvement of manual and other rehabilitation therapies.
7. Assessment of effectiveness of techniques with special attention to the most questionable ones.

The debate between supporters and detractors of physiotherapy and manual therapy is often caused by limited knowledge. Objective measurement tools, properly used by qualified personnel, are urgently needed to document and validate widely used rehabilitation procedures.

In conclusion, the proposed approach is needed for the progress of rehabilitation sciences, functional medicine and manual therapy, as well as for reducing treatment time and costs for the patients and for the health delivery system, and for strengthening confidence in science and contributing to its development.

Catherine Disselhorst-Klug, PhD

Head of the Department of Rehabilitation & Prevention Engineering
Institute of Applied Medical Engineering
RWTH Aachen University
www.rehabilitation-engineering.com

It is obvious that the profession of physiotherapist is facing considerable challenges in the near future that will change their daily work. This is not only related to the steadily growing number of elderlies in the western society who need rehabilitation more often and which creates increasing financial pressure on the health care systems. It can be assumed that in near future only rehabilitation measures will be covered by the health care systems, of which the evidence has been proven. To adapt to the future challenges, physiotherapists will have to transform more and more from artisans to scientists and will have to defend the methods they use with scientific arguments. This can only be achieved by education, which enables them to meet other scientists at eye level with an equivalent academic degree (MSc or PhD), to find and to make valid arguments and to represent scientific reputation in the form of publications, projects and international visibility.

Technical measurement systems will be indispensable in physiotherapy in the future. Even today they allow the implementation of objective studies and provide quantitative measures, which enable the approval of evidence of physiotherapeutic methods. In addition, they will support the therapist in his work and enable therapy on demand for the patients. The prerequisite for this, however, is that physiotherapists not only use technical systems but also understand their interaction with the human body. This requires basic skills in mathematics, mechanics, electrical engineering, information technology as well as risk and mistake management and, furthermore, knowledge about muscular biomechanics, biomechanics of movement and central nervous control strategies. Internationally, this is already being taught in many schools offering an academic degree (MSc or PhD) in physiotherapy. In these schools, physiotherapists are trained to become scientists, not operators who only treat patients. In some countries like Germany or Italy, however, most schools for physiotherapy still focus on patient care rather than academic education. Furthermore, in these countries there is lack of teachers who can provide the needed contents and a lack of suitable teaching materials. As a result, graduates could face future disadvantages compared to their better educated international colleagues.

The outcome of the CoMES project is a first step to overcome the gap between scientific information and state-of-the-art knowledge of physiotherapists. Interactive web-based courses open new ways for physiotherapists to acquire the necessary knowledge. CoMES initially focuses on surface electromyography, a method with high potential for the physiotherapy of the future. The knowledge of (bio)mechanics, electrical engineering, signal processing and central nervous control strategies necessary for the understanding of surface EMG is provided in individual modules adapted to this task. Detailed information is given about the use, interpretation and risks in reading of surface-EMG. Since the material is free to use it is easy to be (and should be) integrated in the teaching programmes for physiotherapy.

In Germany education of physiotherapists is changing. Scientific elements are more and more common now in many schools and academic degrees allowing to get a PhD in physiotherapy will come soon. Education of physiotherapists in Aachen has a focus on technical systems and our physiotherapy students get the necessary skills to understand these systems and their effects. The teaching materials developed within CoMES will help to broaden and consolidate their knowledge in

surface EMG. We hope to give in this way our students the tools they need for the physiotherapy of the future.

The CoMES project makes a significant contribution to this and I hope that many similar projects will follow in the future on related topics.

Usha Kuruganti, P.Eng. PhD

Professor,
Co-Director, Andrew and Marjorie McCain Human Performance Laboratory
Faculty of Kinesiology, University of New Brunswick
Fredericton, NB, E3B 5A3 CANADA

It is a pleasure to comment on the work of Dr. Merletti and his colleagues on the Project CoMES series of teaching modules. The modules were designed as part of a series of interactive teaching materials on surface electromyography (sEMG). The intended audience for this series includes physiotherapists, kinesiologists, movement scientists and others in the field.

The teaching material is extremely relevant to the fields of rehabilitation engineering, physical and occupational therapy, ergonomics and human factors engineering. Furthermore, speaking as a professor in the Faculty of Kinesiology, the material is well prepared to be integrated with both our undergraduate and graduate courses in the kinesiology science programs. Traditionally, the students have viewed sEMG as a black box, one in which signals are recorded from the skin's surface and then, once the data has been processed, some conclusions can be made. I have found that students are very capable of understanding greater depths of the origins of the signal and its potential for improved understanding of muscle function.

Technological advances in the field of sEMG including multichannel or 2-Dimensional array systems increased our understanding of the properties of the signal. However, the inclusion of this material in undergraduate and graduate teaching in kinesiology has been limited. There are courses that offer more details in the technology and several excellent textbooks have been written (many by Dr. Merletti and his colleagues). However, the advantage of the teaching modules presented in this project is the clear and logical sequencing of information from basic theory to more advanced concepts. Each module begins with the presentation of why the material is important and the learning objectives. In addition, definitions are provided as needed. This is very helpful for students, particularly those who may not have seen the material previously. In addition, the use of diagrams is extremely helpful and will aid students in understanding and acquiring the information.

Recently (Fall 2018) I integrated concepts from the materials presented in Project CoMES into a graduate course in advanced neuromuscular physiology. In particular the following modules provided important insight to the course: Module 2 *Basic Biomechanics*, Module 3 *Basic Electrical Phenomenon*, and Module 4 *Basic Signal Analysis*.

Overall, the material presented is a very important addition to the field of kinesiology. The logical sequencing from the origins of the sEMG to the potential applications is well presented and provides detailed information for researchers and practitioners. This series provides both fundamental and advanced information to ensure that practitioners in the field have a good understanding of the power of sEMG and its use in human movement analysis.

Samuel D'Emanuele, MSc
School of Exercise and Sport Sciences, University of Torino, Torino, Italy

Project CoMES is a first attempt to fill a need that Prof. Merletti (and many others) personally experienced, that is the lack of competences necessary to establish a communication and a link between physiotherapists, kinesiologists and biomedical engineers. For many reasons, the basic knowledge required for an effective common language between these figures is lacking despite the progressive merging of these professions that, in the future, will have to interact more and more strictly.

Today, university students in movement sciences and physiotherapy still look suspiciously to any teaching that is not strictly practical and/or professionally rewarding. For example, the potential provided by sEMG in their profession is largely not known.

The Bachelor Curriculum of the Academic School of Hygiene and Movement Sciences (SUISM) in Torino offers one course in Physics of only 16 hours, which is insufficient to provide even the most elementary knowledge of mechanical/electrical phenomena and signal processing. Nevertheless, the curricula of two Master level degrees include courses of 8 credits that also concern basic electromyography and its applications. In addition, an optional course on "Research Laboratory" includes notions about sEMG and provides opportunities to use equipment and perform acquisition and processing of this signal.

Project CoMES aims to fill these gaps and reduce the differences between the Italian and the International quality of education and training in the field.

CoMES material presents a teaching progression from basic high school physics up to the concepts concerning the sEMG signal and its applications. Three factors make this material particularly valuable for dissemination of sEMG knowledge in Italy: the bilingual (English and Italian) version, the fact that it is free and the important fact that it has been prepared in collaboration with three physiotherapists, for physiotherapists.

A future possible improvement could be to consider studies in which sEMG has been used as an investigation technique to assess the effectiveness of various exercises and motor tasks, for example concerning sport training. This would likely increase the interest of students of movement sciences by demonstrating applications in fields with which they are familiar. In addition, video lectures on specific topics would be very helpful.

It should be an objective of the Schools and of their Professors to take this opportunity to trigger interest and passion of the students toward this topic allowing them to grow in a direction very important for their future. This is important because this future has already started.