A dissemination article published by "Science, Technology and Innovation Projects", British Publishers (UK), Sept. 2008, about projects developed by the Laboratory for Engineering of the Neuromuscular System, Politecnico di Torino (Italy).

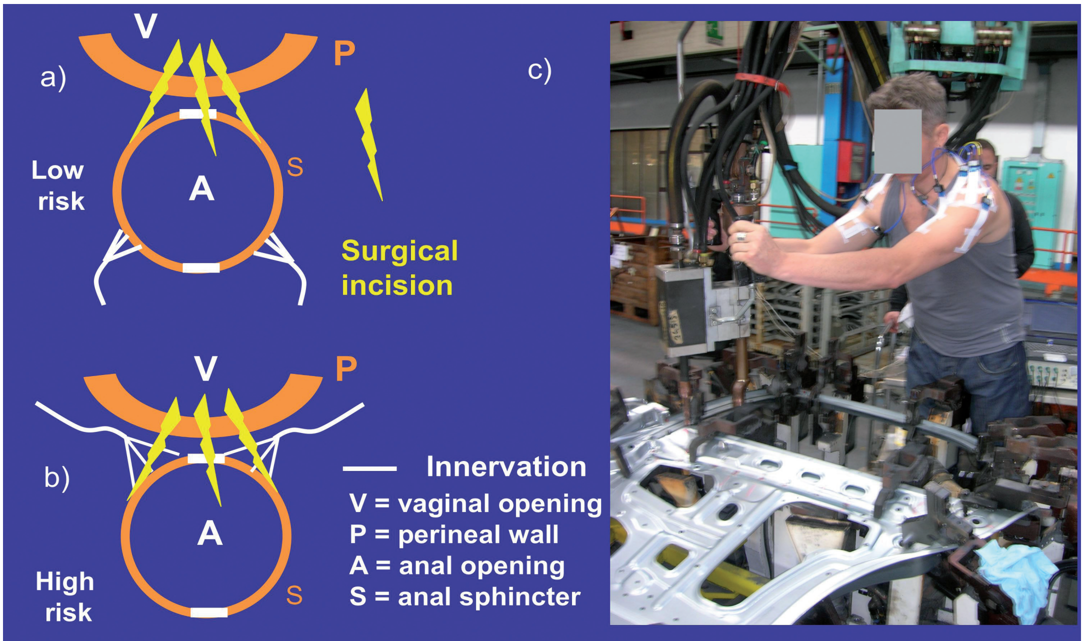

Figure 3. a), b) Knowing the location of anal sphincter innervation helps the gynaecologist in performing episiotomy. c) Knowing muscle activity in industrial jobs helps to design better workstations

Muscles are crucial to our daily functioning, and improving our understanding of how they work will bring real benefits. Several institutions have prioritised research into this area, and the sum of their efforts is much more than its parts, says **Roberto Merletti** of Politecnico di Torino and COREP

Space, sport, ergonomics and sphincters

It is hard to imagine a life without movement. The ability to control muscles and movements is a prerequisite to fulfilling commonplace daily functions like walking, biting and chewing, or working at an assembly line, not to mention delivering a child, or retaining or releasing urine and faeces – both areas where improving our understanding of sphincters could have a significant impact. However, muscles tend not to be used much on the International Space Station – where the body has no weight – and thus astronaut's muscles can quickly deteriorate while they are in space.

Both the European and Italian Space Agencies (ESA and ASI) are well aware of the problem, and the two have thus been supporting research aimed at designing and assessing countermeasures. This research addresses practical issues: which exercises would work best? Would electrical stimulation bring about a significant improvement?

These are questions which engineers at the Laboratory for Engineering of the Neuromuscular System (LISiN) at Politecnico di Torino (Italy) are working hard to answer. Thus far the work has focused on observing muscles – through the window provided by the electrical signals that they generate – in order to decode the control strategies adopted by the brain, monitor force and fatigue, and also prevent work-related disorders and pelvic floor lesions associated with giving birth or having undergone surgery. It must also be emphasised that this kind of work is of relevance in other areas too, and thus research in other subjects is

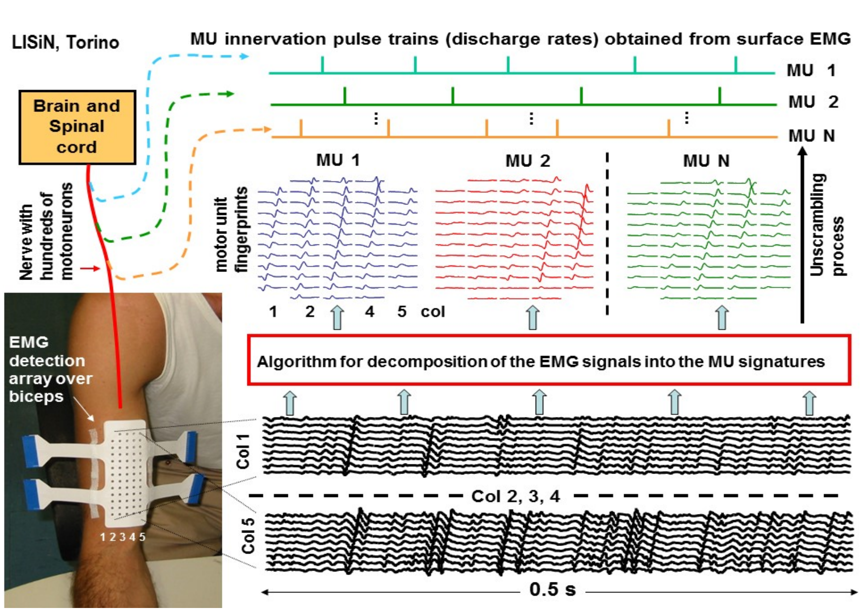

Figure 1. Decomposition of multichannel surface EMG into its constituent motor unit action potential trains provides information about central control strategies and peripheral muscle phenomena (fatigue)

being accelerated as well. "Microgravity effects on skeletal muscles" (MESM) – supported by ESA and "Technology for Anal Sphincter analysis and Incontinence" – (TASI) supported by Compagnia di San Paolo in Italy and the Fresenius Foundation in Germany, are just two of the many other projects LISiN coordinates.

Muscle electrical signals

In the human body hundreds of motoneurons (packed in a nerve) are used to carry the brain's central commands to the muscles, which then act upon them. Each motoneuron branches out to innervate hundreds of muscle fibers that form sub-motors called Motor Units (MU), they are then recruited and intelligently driven by trains of frequency modulated electrical pulses (in the range of 6 to 40 pulses per second). These pulses are generated at the spinal cord level by neural networks that integrate the central and peripheral information. Waves of depolarisation (like tiny batteries) then propagate along the muscle fibers. This process starts at the neuromuscular junction, where the nerve branches connect to the fibers, and finishes at the tendons. Through a number of intermediate steps these waves trigger the contraction process. They also generate electrical fields that add up and result in the distribution of time-changing electrical voltages on the skin with amplitude of 0.1-2 mV and a frequency spectrum ranging from 10 Hz to 400 Hz.

These voltages, which are detected on the skin with a set of electrodes, are known as the electromyogram (EMG). This signal can be compared with the noise which is typically generated when a large number of people talk simultaneously in a hall (they represent the MUs of the muscle). The parallels can be extended further; indeed microphones on the walls play the role of the electrodes on the skin in this situation. Can individuals be located and their voices be unscrambled from the noise? Can EMG features tell us about brain motor control strategies or muscle fatigue? Can they be used to monitor atrophy, disorders, or the effectiveness of treatment and sport training? After decades of research the answers to these questions are beginning to emerge.

If the market is to be stimulated then dissemination and teaching efforts aimed at generating greater public awareness must be accelerated. With awareness will come real enthusiasm for the EMG techniques

Fig 1 shows a 5x13 electrode array placed on a biceps brachii. Two sets of signals (from column 1 and 5) are shown on the right. A sophisticated unscrambling algorithm, developed at the University of Maribor in Slovenia, extracts the 'fingerprints' of each MU and identifies the discharge rate of its motoneuron. Fingerprints provide information about the MU; namely the location of their innervation, their anatomical features and also their levels of fatigue. Meanwhile, the discharge rates provide information about the control strategies adopted by the brain: strategies which typically involve regulating muscle force by recruiting and de-recruiting the MUs and adjusting their discharge rate. A collection of electrode types and EMG amplifiers is used for this purpose.

A wide range of applications

Among other things, the electrode array provides a spatial map of the EMG signal intensity, over one or more muscles. Fig 2 shows a signal amplitude map collected from the upper trapezius muscle. The central blue region corresponds to the innervation zone (where the branches of the motoneurons connect to the muscle fibers), while the red and brown regions correspond to high signal locations. The numbers identify the 65 electrodes. The load sharing between muscles could be extracted from a larger array placed on a limb or on the back. This knowledge is of paramount importance in both space medicine and sports (particularly in order to tune and focus countermeasures and training), and also in ergonomics (where it can be very helpful in terms of monitoring fatigue and designing better workstations).

Fig 3 shows a worker using a spot welding machine to join parts of a car body. The activity levels of his back, shoulder and upper arm muscles are being monitored so as to study the arrangements that will help optimise the time taken to perform this task, lower the intensity of it or control it – this can be done through the Intelligent Work Assistant Devices (IWAD) that have been developed within the European Projects CybermanS. The cost of work-related musculoskeletal disorders is sizeable – ranging from 1 per cent to 3 per cent of the GNP of the various European countries in which it occurs. Therefore, research to reduce the number of such disorders by means of proper workstation design and IWADs could have a significant economic and societal impact.

There are many applications for COREP activity in the neurological field, where needles are routinely used for EMG detection. However, for the purposes of this article we will focus on another area, one with wide relevance. Episiotomy is a minor surgery frequently applied to facilitate child birth. An incision is performed into the perineal wall to prevent spontaneous lacerations. The innervation of the anal sphincter varies from person to person, and in about 4 per cent of European cases (approximately 80,000 women per year) the anal sphincter is partially damaged or

Business perspectives

There is a large potential market for non-invasive EMG devices. However, growth in the market has thus far been slow, something that can be attributed, in part, to a general lack of user knowledge about the available technology. The consequent lack of demand from clinicians for the products leads manufacturers to maintain the status quo, a situation from which the public is losing out.

If we consider just the gynaecological application, a disposable anal probe could cost as little as €20. With about 4.5 million children being born in Europe every year, the market could potentially reach €90 million per annum

denervated. Minor or major forms of incontinence may later ensue, with the severity depending on the age of the patient and the degree of the lesion. A cylindrical probe with one or more circumferential arrays of electrodes may be used to locate the innervation zones before delivery. Using this information, the gynaecologists may be able to gauge how to perform the episiotomy more accurately – or alternatively decide not to take the risk involved with the operation. Reducing the number of episiotomy-related cases of incontinence would have a significant impact on the quality of life of mothers and provide them with long-term peace of mind, a goal the COREP and Politecnico di Torino are working towards.

If the market is to be stimulated then dissemination and teaching efforts aimed at generating greater public awareness must be accelerated. With awareness will come real clinical enthusiasm for the EMG techniques. If we consider just the gynaecological application, a disposable anal probe could cost as little as €20. With about 4.5 million children being born in Europe every year, the market could thus potentially reach €90 million per annum. This is the kind of potential that initially prompted the research of COREP and the Politecnico di Torino, and the results that have been generated thus far are encouraging researchers to redouble their efforts. ★

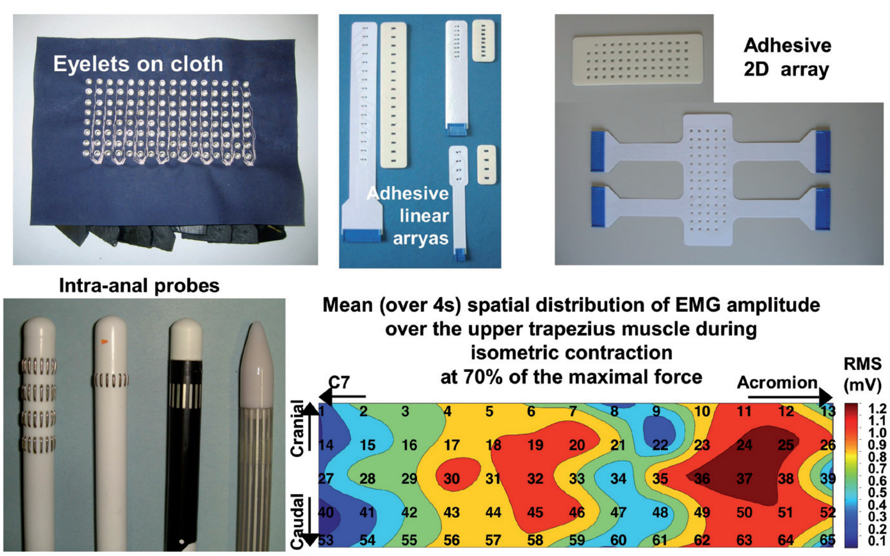

Figure 2. Examples of electrode arrays for skeletal and anal sphincter muscles and example of activity map of the upper trapezius during a strong contraction

At a glance

Main LISiN's Projects

- "Cybernetic Manufacturing System" (CyberManS), EU.Coordinator: alessandro.levizzari@crf.it
- "Microgravity Effects on Skeletal Muscles" (MESM), ESA. Coordinator: roberto.merletti@polito.it
- "Ostheoporosis and Muscle Atrophy" (OSMA), ASI. Coordinator: alberta.zallone@uniba.it
- "Technology for Anal Sphincter analysis and Incontinence" (TASI), Fresenius Stiftung and Comp. di San Paolo. Coordinator: roberto.merletti@polito.it

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Roberto Merletti

Professor of Engineering of the Neuromuscular System at Politecnico di Torino, Italy

Roberto Merletti is director of Engineering of the Neuromuscular System at Politecnico di Torino, Italy. He is director of LISiN, coordinator of MESM and TASI and partner of OSMA and CyberManS. After graduation from Politecnico di Torino, he obtained his PhD from The Ohio State University and was Associate Professor for five years at Boston University. A Senior Member of IEEE and Fellow of the International Society for Electrophysiology and Kinesiology, Prof. Merletti is author or coauthor of over 150 publications in international journals and a worldwide recognized expert in non invasive EMG.