Master in "Advanced Technologies in Rehabilitation"

Background

For several years now Bioengineering has been involved in developing technologies to improve functional evaluation and physiotherapy planning and with a particular focus on subjects with neuromuscular disorders. Although these advancements push physiotherapists to be tuned with their use in functional assessment and clinical treatment, there is still a risk that physiotherapists continue to consider technologies as a threat to their profession rather than as useful instruments for clinical practice.

To improve the scientific and clinical spread of technologies in the rehabilitation field, collaboration and competency sharing between engineers and physiotherapists is an emerging goal. However, engineering needs to develop technologies with a focus on the rationale of physiotherapy planning and physiotherapy needs to move on from preserving traditional and non-technological models.

Universities play an important role in promoting the use of technologies in rehabilitation by offering educational programs able to integrate motor control neurophysiology, rationale of physiotherapy planning, and bioengineering directed at both physiotherapists and rehabilitation engineering. Currently, Bachelor degree programs exclude any interdisciplinary training due to their already demanding course contents, and only a handful of postgraduate programs train physiotherapists and bioengineers in the theory, rationale, and use of technologies to support rehabilitation planning and outcome measurement.

Master program objectives

To introduce theory, rationale, and applications of technologies used in motor rehabilitation.

Candidates

Physiotherapists and occupational therapists with a licence to practice and bioengineers.

Program provider

This Master program is promoted by the Department of Biomedical Sciences of Humanitas University (Pieve Emanuele, Milan), in collaboration with the Politecnico of Milan and the Scientific Institute Don Gnocchi Foundation (Milan).

Scientific Board

Director:

Prof. Roberto Gatti (Humanitas University)

Scientific board:

Dr. Davide Cattaneo (Don Gnocchi Foundation, Milan),
Prof. Christian Cipriani (School of Advanced Studies Sant'Anna, Pisa),
Prof. Maria Laura Costantino (Politecnico of Milan),
Prof. Dario Farina (Imperial College London),
Prof. Carlo Frigo (Politecnico of Milan),
Prof Raffaello Furlan (Humanitas University),
Prof. Manuela Galli (Politecnico of Milan),
Prof. Marco Gazzoni (Politecnico of Turin),
Dr. Johanna Jonsdottir (Don Gnocchi Foundation, Milan),
Prof. Roberto Merletti (Politecnico of Turin)

Program content

The attainment of the Master program implies the acquisition of **60 ECTS** (1 ECTS = 25 hours) divided over the follows modules and activities:

- Modules A and L: acquisition and analysis of bioelectric and myoelectric signals + Lectures (**8 ECTS**),
- Modules B and L: instrumental analysis of motor performance + lectures (**16 ECTS**),
- Module C and L: technologies for therapeutic exercise + lectures (**20 ECTS**),
- Thesis (**6 ECTS**),
- Internship (**10 ECTS).**

Hours of Study

One ECTS is equivalent to **6 hours of lesson and 12 hours of internship**.
One day is equivalent to **7 hours of lesson** (9.00-13.00 and 14.00-17.00).
One week is equivalent to **6 days of lesson**.

Program timetable

Period	Activities	Overall CFU
Sunday 16/01/22 Saturday 29/01/22 (Except Sunday 23/1/22)	- Bioelectric and myoelectric signals (8 CFU) - Instrumental analysis of motor performance (7 CFU)	
Monday 13/06/22 Saturday 25/06/22 (Except Sunday 19/6/22)	- Instrumental analysis of motor performance (9 CFU) - Technologies for therapeutic exercise (5 CFU)	
Sunday 02/10/22 Saturday 15/10/22 (Except Sunday 9/10/22)	- Technologies for therapeutic exercise (15 CFU)	

MASTER PROGRAMME

Module L **Keynote lectures**

- Dario Farina: “From neurophysiology to bioengineering of motor control”
- Robert Riener: “Robotics and rehabilitation: myths and reality”
- Roberto Gatti: “Motor impairment kinesiology: from clinical assessment to instrumental quantification”
- Marco Barbero: “Helical axis displacement in normal and pathological joints”
- Carlo Frigo: “A dynamic model of quadriceps and hamstrings function during gait”
- Giovanni Buccino: “Rationale and application of action observation training in motor rehabilitation”

Module A - Acquisition, analysis and interpretation of bioelectric and EMG signals
Coordinators: Prof. Marco Gazzoni and Prof. Roberto Merletti
The objective of this module is to present the methodologies for acquisition, analysis, and interpretation of bioelectric (in particular myoelectric) signals, considering their features from a physiological point of view. Analysis includes the signals processing in the time-domain, frequency-domain, and their interpretation by means of modeling.

Topic	Lecture topics	Teacher	Hours
Mathematics and physics of physiological electrical signals	Review of math and basic physics of signals. Signals in space and in time. Fourier expansion of a signal and concept of amplitude and power spectrum. Concept of bandwidth of a signal. Concept of filter.	Roberto Merletti	7
	Basic electrophysiology. Origin and informative content of the main bioelectric signals: ECG, EEG, sEMG, nEMG. Modeling of signal generation	Roberto Merletti	4
	Physiological signals in space (over the skin/chest) and in time. Spatial filter. Bipolar and multichannel array sEMG.	Alberto Botter	3
Detection of bioelectric signals. Analysis of bioelectric signals and surface EMG	Transducer, sensor. Conditioning and amplification of a signal. The electrode as a transducer. Sampling and A/D conversion of bioelectric signal.	Giacinto Luigi Cerone	4
	Power line interference, noise and movement artefacts. ECG interference. Focus on sEMG.	Giacinto Luigi Cerone	3
	Demo. Tips and tricks: “how should bioelectric signals (sEMG) be properly detected”. Reduction of power line interference, noise, movement artefacts, ECG interference.	Roberto Merletti, Taian Vieira, Marco Gazzoni	3
EMG Signal quantitative variables	Processing and feature extraction. Temporal features of sEMG. Muscle activation intervals. Muscle activation level. Estimation of muscle fiber conduction velocity.	Taian Vieira	2
	Spectral features of sEMG and their physiological	Taian Vieira	2

	significance.		
	Myoelectric manifestations of muscle fatigue.	Marco Gazzoni, Taian Vieira	3
	Factors influencing sEMG in isometric and non-isometric contractions (Heterogeneous spatial distribution of sEMG. Identification of innervation zones etc..).	Marco Gazzoni	3
	Decomposition into fundamental patterns (synergies) (Non Negative Matrix Factorization).	Andrea D'Avella	4
Clinical applications	Clinical examples of applications. Examples of common mistakes and misinterpretations. Identification of poor signal quality. Gait analysis, control of prosthesis and exoskeletons, spasticity assessment and other applications in sport and occupational medicine.	Isabella Campanini, Andrea Merlo,	10
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Module B - Instrumental analysis of motor performance
Coordinators: Prof. Carlo Frigo and Prof. Manuela Galli
The objective of this module is to present technologies useful for assessment of motor performance of subjects with motor impairment. Technologies will be introduced after the physics and biomechanics presentation.

Topics	**Lecturer**	**Hours**
Basics of applied biomechanics	Carlo Frigo	14
Basics of biomechanical data processing	Manuela Galli	7
Torque measure: isometric, isotonic and isokinetic dynamometers	Nicola Maffiuletti	4
Neuromuscular assessment in motor functions: EMG	Nicola Maffiuletti	3
Arthrogenous muscle inhibition: twitch interpolation technique	Nicola Maffiuletti	4
Balance: static and dynamic posture assessment. Systems for data acquisition and clinical data analysis	Davide Cattaneo Elisa Gervasoni Rita Bertoni Maurizio Petrarca	11
Movement analysis: kinematics (spatio-temporal parameters, joint angles,…)	Manuela Galli	14
Movement analysis: kinetics (internal and external joint torques, ground reaction forces and COP, mechanical energy)	Carlo Frigo	7
Gait Analysis (standardized protocols, models, joints kinetics and kinematics, EMG, quality assessment, clinical cases): clinical cases	Roberto Gatti Maurizio Petrarca Maria Gr Benedetti Luigi Piccinini	14
User-friendly devices for motor performance analysis in clinical practice (IMU, and wearable systems. Instrumented clinical test: iTUG, i10-minutes walking test, i6-minutes walking test, etc..)	Matteo Zago Federico Temporiti	17

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Module C - Technologies for therapeutic exercise **Coordinators: Prof. Maria Chiara Carrozza and Prof. Roberto Gatti** The objective of this module is to present technologies used in physiotherapy planning. The module is designed to introduce the devices after a literature review on their application, efficacy, and posology.		
Topics	**Lecturer**	**Hours**
Neurophysiology of motor control and motor recovery	Riccardo Fesce, Francesco Bolzoni	21
Robots and systems for rehabilitation Exoskeletons and device for rehabilitation Clinical trials and assessment of biorobots for rehabilitation Machine learning and algorithm for control	Stefano Mazzoleni, Simona Crea, Chiara Arienti, Andrea Mannini	28
Rationale and evidence on multisensory stimulation training: Use of cognitive facilitation in rehabilitation Rehabilitation with augmented or immersive virtual reality systems Mechanical Peripheral Stimulation	Roberto Gatti Raffaello Furlan Andrea Turolla	21
Rationale of balance training: Balance rehabilitation with robotic systems Balance rehabilitation with stabilometric platforms	Davide Cattaneo Elisa Gervasoni Rita Bertoni Maurizio Petrarca	14
Electrical stimulation systems: applications of TMS in rehabilitation; applications of tDCS in rehabilitation; functional electrical stimulation systems	Francesca Baglio Simona Ferrante	7
Advanced prosthetics and control of upper and lower limb	Christian Cipriani Francesco Clemente Leonardo Cappello Simona Crea	12
Continuity of care: telerehabilitation	Fabrizio Natali	7
User-friendly devices for motor rehabilitation: biofeedback on force, ROM and sEMG; use of Apps; Other tools (es. Movies with motor content, etc.)	Paola Adamo, Johanna Jonsdottir	7
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Internship **Coordinators: Dr Davide Cattaneo and Dr Johanna Jonsdottir**			
Topics			**CFU**
During the period of the Master, the students are required to attend four weeks of internship (hospitals, laboratories, companies). The planning (place, objective etc.) of the internship must be presented to a specific Commission by the 31 March 2022			**10**

MASTER PLANNING (2022)

First period of lessons	Morning	Afternoon
Sun 16 Jan	Lecture Farina / Review of math and physics. Signals in space and in time (Merletti)	
Mon 17 Jan	Basic electrophysiology. Physiological signals in space and time (Merletti, Botter)	
Tue 18 Jan	Transducer sensor. Power line interference, noise, artefacts (Cerone)	
Wed 19 Jan	Reduction of power line interference, noise, artefacts. EMG signal quantitative variables (Merletti, Vieira, Gazzoni)	
Thurs 20 Jan	EMG quantitative variables (Gazzoni, Vieira)	
Fri 21 Jan	Decomposition into fundamental patterns. Clinical application (D'Avella, Campanini, Merlo)	
Sat 22 Jan	Clinical application (Campanini, Merlo)	
Sunday 23 January		
Mon 24 Jan	Lecture Riener / Basics of applied mechanics (Frigo)	
Tue 25 Jan	Basics of applied mechanics (Frigo)	
Wed 26 Jan	Basics of biomechanical data processing (Galli)	
Thurs 27 Jan	Static and dynamical posture assessment. Acquisition and clinical data analysis (Cattaneo, Gervasoni, Bertoni)	Torque measure: isometric, isotonic and isokinetic dynamometers (Maffiuletti)
Fri 28 Jan	Neuromuscular assessment and AMI twitch interpolation technique (Maffiuletti)	
Sat 29 Jan	Static and dynamical posture assessment. Acquisition and clinical data analysis (Cattaneo, Gervasoni, Bertoni, Petrarca)	

Second period of lessons	Morning	Afternoon
Mon 13 June	Lecture Gatti / Movement analysis: kinematics (Galli)	
Tue 14 June	Movement analysis: kinematics (Galli)	
Wed 15 June	Movement analysis: kinetics (Frigo)	
Thurs 16 June	Gait analysis (Gatti, Benedetti)	
Fri 17 June	Gait analysis (Petrarca, Piccinini)	
Sat 18 June	Neurophysiology of motor control and motor recovery (Fesce, Bolzoni)	
Sunday 19 June		
Mon 20 June	Lecture Frigo / Neurophysiology of motor control and motor recovery (Fesce, Bolzoni)	
Tue 21 June	Neurophysiology of motor control and motor recovery (Fesce, Bolzoni)	
Wed 22 June	Rehabilitation engineering, telerehabilitation (Mazzoleni)	
Thurs 23 June	Robots and system for rehabilitation (Mazzoleni)	
Fri 24 June	Esoskeleton and device for rehabilitation (Crea)	
Sat 25 June	Clinical trials and machine learning (Arienti, Mannini)	

Third period of lessons	Morning	Afternoon
Sun 2 Oct	Lecture Barbero / Multisensory stimulation training and mechanical peripheral stimulation	

		(Gatti, Furlan)
Mon 3 Oct	Multisensory stimulation training and virtual reality (Gatti, Turolla)	
Tue 4 Oct	Virtual reality (Turolla)	
Wed 5 Oct	Balance training with robotics and stabilometric systems (Cattaneo, Gervasoni, Bertoni)	
Thurs 6 Oct	Balance training with robotics and stabilometric systems (Cattaneo, Gervasoni, Bertoni, Petrarca)	
Fri 7 Oct	Electrical stimulation system (TMS, tDCS, FES) (Baglio, Ferrante)	
Sat 8 Oct	Continuity of care: telerehabilitation (Natali)	
Sunday 9 October		
Mon 10 Oct	Lecture Buccino	Advanced prosthetics and control of upper and lower limb (Cipriani, Clemente, Cappello, Crea)
Tue 11 Oct	Advanced prosthetics of upper and lower limb (Cipriani, Clemente, Cappello, Crea)	
Wed 12 Oct	User friendly devices for movement analysis (Zago, Temporiti)	
Thurs 13 Oct	User friendly devices for movement analysis (Zago, Temporiti)	
Fri 14 Oct	User friendly devices for movement analysis (Zago, Temporiti)	User friendly devices for motor rehabilitation (Adamo, Jonsdottir)
Sat 15 Oct	User friendly devices for motor rehabilitation (Adamo, Jonsdottir)	

MATR teachers

Name	Email address	Affiliation	Mod	Topic
Adamo Paola	paola.adamo@humanitas.it	Physiotherapist Humanitas Hospital, Rozzano	C	User-friendly devices for motor rehabilitation biofeedback on force, ROM and sEMG; use of Apps. Other tools
Arienti Chiara	carienti@DONGNOCCHI.IT	Researcher Don Carlo Gnocchi Foundation, Milan	C	Clinical trials
Baglio Francesca	fbaglio@dongnocchi.it	Neurologist Don Gnocchi Foundation, Milan	C	Electrical stimulation systems: applications of tDCS in rehabilitation
Barbero Marco	marco.barbero@supsi.ch	Physiotherapist SUPSI, Lugano Switzerland,	L	Helical axis displacement in normal and pathological joints
Benedetti Maria Grazia	mariagrazia.benedetti@ior.it	Physiatrist Rizzoli Orthopedic Institute	B	Gait Analysis: standardized protocols, models, joints kinetics and kinematics, EMG, quality assessment, clinical cases
Bertoni Rita	rbertoni@dongnocchi.it	Physiotherapist Don Gnocchi Foundation, Milan	B, C	Balance: static and dynamic posture assessment. Systems for data acquisition and clinical data analysis. Balance rehabilitation with robotic systems and stabilometric platforms
Bolzoni Francesco	francesco.bolzoni@hunimed.eu	Physiologist Humanitas University, Pieve Emanuele	C	Neurophysiology of motor control and motor recovery
Botter Alberto	alberto.botter@polito.it	Engineer Politecnico of Turin (Lisin)	A	Mathematics and physics of physiological electrical signals: Physiological signals in space and in time. Spatial filter. Bipolar and multichannel array sEMG
Buccino Giovanni	buccino.giovanni@hsr.it	Neurologist Vita-Salute San Raffaele University, Milan	L	Rationale and application of action observation training in motor rehabilitation

Cappello Leonardo	leonardo.cappello@santannapisa.it	Engineers School of Advanced Studies Sant'Anna, Pisa	C	Advanced prosthetics and control of upper and lower limb
Campanini Isabella	Isabella.Campanini@ausl.re.it	Physiotherapist Azienda USL-IRCCS di Reggio Emilia	A	Clinical examples of applications. Common mistakes and misinterpretations. Identification of poor signal quality. Gait analysis, control of prosthesis and exoskeletons, spasticity assessment and other applications
Cattaneo Davide	dcattaneo@dongnocchi.it	Physiotherapist Don Gnocchi Foundation, Milan	B, C	Balance: static and dynamic posture assessment. Systems for data acquisition and clinical data analysis. Balance rehabilitation with robotic systems and stabilometric platforms
Cerone Giacinto Luigi	giacintoluigi.cerone@polito.it	Engineer Politecnico of Turin (Lisin)	A	Analysis of bioelectric signal and surface EMG. Transducer, sensor. Conditioning and amplification of a signal. The electrode as a transducer. Sampling and A/D conversion of bioelectric signal. Power line interference, noise and movement artefacts. ECG interference. Focus on sEMG
Cipriani Christian	christian.cipriani@santannapisa.it	Engineers School of Advanced Studies Sant'Anna, Pisa	C	Advanced prosthetics and control of upper and lower limb
Francesco Clemente	francesco.clemente@santannapisa.it	Engineers School of Advanced Studies Sant'Anna, Pisa	C	Advanced prosthetics and control of upper and lower limb
Crea Simona	simona.crea@santannapisa.it	Engineer School of Advanced Studies Sant'Anna, Pisa	C	Exoskeleton and device for rehabilitation and advanced prosthetics
D'Avella Andrea	adavella@unime.it	Physiologist University of Messina	A	Decomposition into fundamental patterns (synergies)
Farina Dario	d.farina@imperial.ac.uk	Engineer Imperial College, London	L	From neurophysiology to bioengineering of motor control
Fesce Riccardo	riccardo.fesce@hunimed.eu	Physiologist Humanitas University, Pieve Emanuele	C	Neurophysiology of motor control and motor recovery
Ferrante Simona	Simona.ferrante@polimi.it	Engineer Politecnico of Milan	C	Electrical stimulation systems: functional electrical stimulation systems
Frigo Carlo	carlo.frigo@polimi.it	Engineer Politecnico of Milan	B	Basics of applied biomechanics. Movement analysis: kinetics
Furlan Raffaello	raffaello.furlan@hunimed.eu	Physician (Internal and Sport Medicine) Humanitas University, Pieve Emanuele	C	Mechanical Peripheral Stimulation
Galli Manuela	manuela.galli@polimi.it	Engineer Politecnico of Milan	B	Basics of biomechanical data processing. Movement analysis: kinematics
Gatti Roberto	roberto.gatti@hunimed.eu	Physiotherapist Humanitas University, Pieve Emanuele	L, B, C	Motor impairment kinesiology: from clinical assessment to instrumental quantification. Multisensory stimulation, gait analysis

Gazzoni Marco	marco.gazzoni@polito.it	Engineer Politecnico of Turin (Lisin)	A	Factors influencing sEMG in isometric and non-isometric contractions. Myoelectric manifestations of muscle fatigue. Demo: how should bioelectric signals (sEMG) be properly detected
Gervasoni Elisa	egervasoni@dongnocchi.it	Physiotherapist Don Gnocchi Foundation, Milan	B, C	Balance: static and dynamic posture assessment. Systems for data acquisition and clinical data analysis. Balance rehabilitation with robotic systems and stabilometric platforms
Jonsdottir Johanna	jjonsdottir@DONGNOCCHI.IT	Physiotherapist Don Gnocchi Foundation, Milan	C	User-friendly devices for motor rehabilitation: biofeedback on force, ROM and sEMG; use of Apps. Other tools
Maffiuletti Nicola	maffiuletti@gmail.com	Physiologist Schulthess Clinic, Zurich, Switzerland	B	Torque measure: isometric, isotonic and isokinetic dynamometers. Arthrogenous muscle inhibition: twitch interpolation technique
Mannini Andrea	andrea.mannini@gmail.com	Engineer Don Gnocchi Foundation, Florence	C	Machine learning
Mazzoleni Stefano	stefano.mazzoleni@poliba.it	Engineer School of Advanced Studies Sant'Anna, Pisa and Politecnico of Bari	C	Robots and systems for rehabilitation
Merletti Roberto	roberto@robertomerletti.it	Engineer Politecnico of Turin (Lisin)	A	Review of math and basic physics of signals. Fourier expansion of a signal and concept of amplitude and power spectrum. Concept of bandwidth of a signal. Concept of filter. Basic electrophysiology. Origin and informative content of the main bioelectric signals: ECG, EEG, sEMG, nEMG. Modeling of signal generation. Demo: how should bioelectric signals (sEMG) be properly detected
Merlo Andrea	ingmerlo@me.com	Engineer MerloBioEngineering, Reggio Emilia	A	Clinical examples of applications. Common mistakes and misinterpretations. Identification of poor signal quality. Gait analysis, control of prosthesis and exoskeletons, spasticity assessment and other applications
Natali Fabrizio	fabrizio.natali@humanitas.it	Physiotherapist Humanitas Hospital, Rozzano	C	Continuity of care: telerehabilitation
Petrarca Maurizio	mauriziopetrarca@gmail.com	Physiotherapist "Bambino Gesù" Children's Hospital, Rome	B, C	Balance assessment, Children gait analysis, Balance rehabilitation
Piccinini Luigi	luigi.piccinini@lanostrafamiglia.it	Physiatrist La Nostra Famiglia Association, Bosisio Parini (LC)	B	Children gait analysis: clinical cases
Riener Robert	robert.riener@hest.ethz.ch	Engineer Sensory-Motor Systems Lab, ETH Zurich, Switzerland	L	Robotics and rehabilitation: myths and reality
Temporiti Federico	federico.temporiti@humanitas.it	Physiotherapist Humanitas University, Pieve Emanuele	B	User-friendly devices for motor performance analysis in clinical practice
Turolla Andrea	andrea.turolla@ospedalesancamillo.net	Physiotherapist San Camillo Hospital, Venice	C	Rationale and evidence of multisensory stimulation training. Rehabilitation with augmented or immersive virtual reality system
Vieira Taian	taian.martins@polito.it	Engineer Politecnico of Turin (Lisin)	A	Processing and feature extraction. Temporal features of sEMG. Muscle activation intervals. Muscle activation level. Estimation of muscle fiber conduction velocity. Spectral features of sEMG and

				their physiological significance. Demo. how should bioelectric signals (sEMG) be properly detected. Myoelectric manifestation of muscle fatigue
Zago Matteo	matteo2.zago@polimi.it	Engineer Politecnico of Milan	B	User-friendly devices for motor performance analysis in clinical practice