**Course: BONE AND JOINT DISEASES & TECHNOLOGIES IN REHABILITATION**

**Year (1st-2nd-3rd-4th-5th-6th): 5 th**

**Period (1st-2nd semester – annual): 2nd semester**

**Credits: 11**

**Faculty**: Prof Maurilio Marcacci, Prof Elizaveta Kon, Dr Tommaso Bonanzinga, Prof Giuseppe Massazza, Prof Ezio Lanza, Prof Roberto Gatti, Prof Tommaso Villa, Prof Veronica Cimolin.

**Year/Semester** 5th year /2nd semester
**Credits: 10**

## MUSCULOSKELETAL SYSTEM DISEASES

**Credits: 3**

**Objectives**

The course will highlight the main clinical features of orthopaedics and traumatology, in order to provide a comprehensive overview of the basic clinical presentations and treatment options for a variety of orthopaedic problems, determined from patient clinical history and clinical evaluation. Furthermore, the course will provide a comprehensive view of the semantics of the associated conditions and determine their common mechanisms and unique features.
The module of orthopaedics includes direct lectures to the students, a practical lesson for patient evaluation and interpretations of specific investigations i.e. X ray, CT scans, MRI, for a variety ofdifferent pathologies.

## Prerequisites

Knowledge of anatomy and physiology of the motor system. Basic concepts of biomechanics of motor system.

## Contents

**The student should be able to:**

**Orthopaedics and trauma**

- Describe general terminology, anatomy biomechanics, and function of the body's major joints both in adults and in children.
- Describe the most common articular problems from patient complaints, clinical history and patient examination.
- Describe the most common traumatology problems and limb or life-threatening injuries (trauma

emergencies).
- Discuss the biomechanics of pathological joints and recognize them correctly with further investigations (x-RAY, CT, MRI, etc.).
- Be able to recognize the entity of the disease (classifications) and start a correct therapeutic approach accordingly.
- Identify the differences between a growing and mature skeleton at a basic level.
- Recognise some of the most common congenital deformities.
- Make a differential diagnosis and select the most appropriate initial investigations.

**PATIENT ASSESSMENT SKILLS**

**Proposed outcomes:**
- Perform an accurate and problem-focused musculoskeletal history.
- Perform a targeted musculoskeletal physical examination.
- Select the most appropriate initial investigations.
- Communicate findings efficiently.

**Physical Examination**
- Perform a screening examination e.g. GALS (Gait, Arms, Legs, Spine)
- Examine main joints and spine, including specific tests for pathology.
- Examine an acutely injured patient, including a focused neurological examination.
- Interpret found findings and relate them to the patient's history.

**Extremity/regional examinations to include:**
- Spine
- Hip and pelvis
- Knee
- Ankle and foot
- Shoulder
- Elbow
- Wrist and hand

**Learning/teaching methods:** Lectures; Clinical examination

**Traumatology: general part**

**Learning goals:**

• Discuss the etiopathogenesis of fractures and the biology of fracture healing and remodeling

• Describe the principles of fracture classification

• Describe early and delayed fracture complications (local and systemic)

• Describe general principles of fracture treatment

• Describe traditional and innovative imaging techniques for fracture evaluation, classification, and healing.

• Discuss traumatological complications and emergencies: compartment syndrome, infections, neurovascular compromission.

**Regional Traumatology**

Spine traumatology: Spinal fracture / spinal trauma, Post-traumatic spinal deformities - Describe region-specific fracture complications,principles of fracture treatment, the most common devicesused in fracture fixation

Wrist and hand traumatology: wrist fractures, hand fractures, scaphoid fractures, Metacarpal/phalangeal fractures. Describe principal fractures of the wrist and hand, region-specific fracture complications, principles of fracture treatment, and the most common devices used in fracture fixation

Shoulder and elbow traumatology: Shoulder dislocation, AC joint separation, Clavicle fracture, Biceps tendon and rotator cuff ruptures, humerus fractures, Olecranon fracture, Radial head fracture. Describe principle fractures of Shoulder and elbow, region-specific fracture complications, fracture treatment, and most common devices used in fracture fixation

Hip and pelvis traumatology: Femoral neck fracture, Pubic ramus fracture, femoral diaphysis and peri-trochanteric fractures. Describe principal fractures of the hip and pelvis, region-specific fracture complications, principles of fracture treatment, and the most common devices used in fracture fixation.

Knee region fractures: Patella fracture, tibial plateau and diaphysis fractures, distal femur fractures. Describe region-specific fracture complications, principles of fracture treatment and the most common devices of fracture fixation.

Foot and Ankle traumatology: Ankle fractures-dislocation, ankle sprain, Foot fractures, Metatarsal stress fracture, Achilles tendon rupture. Describe principle fractures of foot and ankle, region-specific fracture complications, principles of fracture treatment, most common devices used in fracture fixation

**Regional Orthopedics**

Hip and Pelvis
Describe etiopathogenesis, diagnostic approach, clinical and anatomo-pathologic features and the main therapeutic strategies of the following pathologies, with the aim of enabling students to perform a differential diagnosis between the most common causes of hip dysfunction.

- Hip Osteoarthritis
- Groin pain

- CAM and Pincher lesion

- Sacroiliac (SI) joint dysfunction

- Greater trochanteric bursitis

- Describe common indications for using different imaging modalities in common diseases of the hip and pelvis.

Knee

Describe etiopathogenesis, diagnostic approach, clinical and anatomo-pathologic features and main therapeutic strategies of the following pathologies, with the aim of enabling students to perform a differential diagnosis between common causes of knee dysfunction.

- Degenerative joint disease/osteoarthritis (unicompartmental or pan-compartmental)

- Meniscus tears and inherent treatment options

- Anterior cruciate ligament (ACL) tear and inherent treatment

- Medial collateral ligament (MCL) sprain

- Osgood-Schlatter's disease

- Tendinitis of the knee: Iliotibial band syndrome (ITBS), patellar/quadricipital tendonitis, pes anserine tendinopathy.

- Patellofemoral pain syndrome

- Describe common indications for the use of different imaging modalities in common diseases of the Knee

Foot and ankle

Describe etiopathogenesis, diagnostic approach, clinical and anatomo-pathologic features and main therapeutic strategies of the following pathologies, with the aim of enabling students to perform a differential diagnosis between common causes of foot and ankle dysfunction.

- Ankle sprains

- Hallux valgus, hallux rigidus and finger deformities

- Pes planus and pes cavus

- Plantar fasciitis and calcaneal spur

- Achilles tendinitis and Hagelund disease

- Morton's neuroma

- Describe common indications for the use of different imaging modalities in common diseases of Foot and Ankle

Shoulder and elbow

Describe etiopathogenesis, diagnostic approach, clinical and anatomo-pathologic features and main therapeutic strategies of the following pathologies, with the aim of enabling students to perform a differential diagnosis between common causes of shoulder and elbow dysfunction.

- Rotator cuff pathology (tear/strain/tendinopathy)

- Impingement syndrome/subacromial bursitis

- Adhesive capsulitis

- Degenerative joint disease/osteoarthritis

- AC Joint degenerative joint disease /osteoarthritis

- Biceps tendinopathy

- Lateral epicondylitis

- Medial epicondylitis

- Olecranon bursitis

- Ulnar nerve entrapment (cubital tunnel syndrome)

- Elbow osteoarthritis

- Describe common indications for the use of different imaging modalities in common diseases of the Shoulder and Elbow

Hand and wrist

Describe etiopathogenesis, diagnostic approach, clinical and anatomo-pathologic features and main therapeutic strategies of the following pathologies to enable students to diagnose differential between common causes of hand and wrist dysfunction.

- Carpal tunnel syndrome, Guyon tunnel syndrome

- Wrist ganglions

- DeQuervain's tenosynovitis

- Dupuytrens contracture

- Carpometacarpal arthritis

- Trigger finger

- Describe common indications for the use of different imaging modalities in common diseases of Wrist and hand

Spine

Learning goals:

Describe etiopathogenesis, diagnostic approach, clinical and anatomo-pathologic features and main therapeutic strategies of the following pathologies to enable students to perform a differential diagnosis between common causes of spine dysfunction

- Degenerative disc diseases

- Spondylolysis, spondylolisthesis and spondylosis

- Scoliosis/kyphosis and complex deformities of the spine
- Nerve root entrapment / low back pain/sciatica /cruralgia/cervicalgia

- Describe common indications for the use of different imaging modalities in common diseases of the Spine and patients presenting with low back pain.

**Paediatric Orthopaedics**

Learning goals

• Understand the differences between the neonatal and adult bone configuration, bone age evaluation, patterns of ossification with growth.

• Congenital malformations: hip (DDH), foot (talipes equinovarus, pes equinus, pes varus), torticollis

• The spine in a growing child: kyphosis, scoliosis, and lower limb length discrepancy

• Diseases of the bone in children: achondroplasia, osteogenesis imperfecta, Paget's disease, Rickets and osteomalacia, osteopetrosis, Ehlers Danlos

• Upper limb pathologies: perinatal trauma, nursemaid's elbow, forearm fractures

• Lower limb pathologies: Legg-Calves-Perthes disease, SUFE, Osgood-Schlatter, genu valgum, genu varum, pes planus

• Osteomyelitis

**Musculoskeletal benign and malignant tumors**

Learning goals:

Musculoskeletal tumors are extremely rare pathologies which are managed by dedicated

orthopaedic surgeons. Students should be able to describe the classification of musculoskeletal tumors and the main clinical features and diagnostic paths of the most common malignant and benign tumors, to understand when to suspect the presence of these challenging pathologies.

• Classification of benign and malignant tumors

• Most common benign bone and malignant tumors: anatomopathological features, signs, symptoms, diagnostic algorithm and principles of multidisciplinary treatment modalities

• Soft tissue tumors: anatomopathological features, signs, symptoms, diagnostic algorithm and principles of multidisciplinary treatment modalities

• Discuss the diagnostic pathway of a patient with bone tumors

• Describe the main interventional radiology procedures applied to bone and joint diseases

• Describe the main indications of interventional radiology for bone and joint diseases

**Introduction to bone and joint imaging**

Learning goals

• Discuss the imaging modalities used to diagnose bone and joint diseases.

• Describe and recognize the normal appearance of bone and joints, focusing on X-ray.

• Describe and recognize the basic X-ray signs of common bone and joint disease

• Describe the main radiological signs of benign and malignant tumors

**Physiopathology principles of bone and joint disease**

Learning goals:

• Describe skeletal tissue (bone, cartilage, ligaments, tendons, muscle, etc.) structure and the cells involved in their development and remodelling

• Describe the mechanisms of bone loss leading to osteopenia and osteoporosis;

• Discuss the major imaging (X ray, DEXA) and laboratory (Ca, P, PTH, etc) findings that are helpful in the

management of patients with bone loss;

• Describe the treatment options in terms of bisphosphonates, calcium and vitamin Dsupplementation, and other options, including potential side effects.

• Describe the basis of articular cartilage pathology, diagnosis and treatment

• Describe the basis of soft tissue (tendons, ligaments, muscles, etc) pathology, diagnosis and treatment

• Describe the principles of regenerative medicine

**Osteoporosis and Osteopenia**

Learning goals:

• Describe the mechanisms of bone loss leading to osteopenia and osteoporosis;

• Discuss the major imaging (X ray, DEXA) and laboratory (Ca, P, PTH, etc) findings that are helpful in the

management of patients with bone loss;

• Describe the treatment options in terms of bisphosphonates, calcium and vitamin Dsupplementation, and other options, including the potential side effects

**Introduction to physical and rehabilitation medicine**

Learning goals:

• Rehabilitation in the future: Rehabilitation 2030
• Epidemiology

• The role of the Physical and Rehabilitation Medicine Physician, Individual Rehabilitation Plan

• Diagnostic, therapeutic, and assessment tools in Rehabilitation

• Strength and movement assessment in rehabilitation: Strength assessment and improvement, Gait cycle and terminology, Physics and instrumental GA, Gait phases and observational gait analysis, GA Reporting and common orthopaedic gait pattern

• Therapeutic approaches in rehabilitation: Evidence-based physical therapies, Interventional therapies

• Clinical rehabilitation – focus on Joints diseases rehabilitation: Spine, Knee

**Teaching methods**
Lectures, given by the most experienced specialists in the field of orthopaedics, will introduce the students to state of the art theory on the most common orthopaedic problems. Lectures will be associated to comprehensive demonstrations on the semeiotic manoeuvres as well as tests for all joint diseases, thus demonstrating how to approach articular malfunction from a clinical aspect.

**Textbook**
- Henry Willmott Trauma and Orthopaedics at a Glance

# ELECTRONIC AND INFORMATIC BIOENGINEERING

**Credits: 4 CFU**

## Objectives

This course provides a comprehensive summary of the main equipment and technologies used in the assessment of patients, data analysis methods and biomechanical data interpretation for clinical and rehabilitative applications. Students will get an overview of state-of-the-art systems available on the market and learn how to apply them in clinical setting.

The main objectives of the course are:

- Description of the main parameters that characterize the motor human function;
- Recall of the physical principles and description of the main equipment/technologies used to measure the parameters of interest;
- description of the methods adopted for the indirect quantification of parameters that cannot be measured directly;
- description of the experimental set-up with practical applications.

Knowledge and understanding: aims, methods and technologies for data acquisition for clinical use in the field of functional evaluation of motor human function (optoelectronic systems, force platform, electromyographic system, movement analysis laboratories, wearable sensors, …) (DD1).
Applying knowledge and understanding/Making judgments: to identify the more adequate technology to quantify the motor performance (DD2).
Learning skills: comparing measurements systems, defining test protocol, analyzing data, describing biomechanical results, evaluating human performance,

## Prerequisite

Knowledge of anatomy and physiology of the motor system. Basic concepts of biomechanics of motor system.

## Contents

**1. Instrument and methods for motion analysis**
1.1. Anatomical-functional review of the neuro-musculoskeletal system
1.2. The variables of interest for the functional evaluation of the movement
1.2.1. Kinematics
1.2.2. Kinetics
1.2.3. Muscle activation: the EMG signal
1.3. Tools and methods for measuring the variables of interest
- 1.3.1. Electrogoniometers
- 1.3.2. Accelerometers
- 1.3.3. Image analysis systems
- 1.3.4. Dynamometers
- 1.3.5. Dynamometric platforms
- 1.3.6. Models for calculating joint reactions and moments
- 1.3.7. Sensor matrices
- 1.3.8. Ergometers
- 1.3.9. Protocols for the multifactorial analysis of locomotion.

**2.** Methods and tools for assessing postural function
2.1. Anatomical-functional review of the balance system, components and interpretative models
2.2. The variables of interest for the functional assessment of postural function
- 2.2.1. Stabilometry
- 2.2.2. Orthostatic and dynamic equilibrium

2.3. Tools and methods for measuring the variables of interest
- 2.3.1. Stabilometers

## Teaching Methods

The course is organized with lessons and with practical activities where the students will learn the use of the equipment and their software for data analysis. Students are encouraged to actively participate to the lectures with questions and comments.

## Assessment

The final test will consist of multiple-choice questions (with only one correct answer) on all the topics covered during the course. The final mark will be proportional to the number of correct answers.

## Texts

- B.Nigg e W.Herzog,, Biomechanics of the musculo skeletal system , Editore: J.Wiley&Sons
- M Nordin, V.H.Frankel, Basic Biomechanics of the Musculoskeletal System, Editore: Lea &Febiger
- Duane Knudson, Fundamentals of Biomechanics, Editore: Springer

# DIAGNOSTIC IMAGING AND RADIOTHERAPY

**Credits: 1**

## Objectives

Provide students with the necessary knowledge and skills to identify and diagnose various bone diseases using different imaging techniques. By the end of this course, students should be able to:

1. Understand the principles and applications of different imaging techniques used in the diagnosis of bone diseases, such as X-ray, CT scan, MRI, and PET scan.
2. Recognize the different types of bone diseases, including osteoporosis, osteoarthritis, bone tumors, and fractures.
3. Learn how to interpret imaging results and correlate them with clinical findings to make accurate diagnoses.
4. Identify the limitations and potential pitfalls of different imaging techniques and know when to use additional imaging modalities.
5. Develop a comprehensive understanding of the role of imaging in the management and treatment of bone diseases.
6. Acquire knowledge of the latest advancements in imaging technology and their application in the diagnosis of bone diseases.
7. Understand the importance of patient safety and radiation protection in diagnostic imaging and know how to minimize radiation exposure during imaging procedures.
8. Develop effective communication skills to convey imaging findings to patients and healthcare providers accurately.

By the end of this course, students should be well-equipped to apply their knowledge and skills to diagnose and manage various bone diseases confidently.

## Prerequisites

Knowledge of anatomy and physiology of the motor system. Basic concepts of biomechanics of motor system.

## Contents

1. Introduction
2. Typical imaging manifestations of common MSK diseases
3. Upper limb
4. Lower limb
5. Spine

### Teaching Methods

Through lectures, group discussions, case studies, and hands-on practice, students will gain a deep understanding of the principles and applications of imaging techniques such as X-ray, CT scan, MRI, and PET scan. Furthermore, the course will emphasize the importance of interpreting imaging results and correlating them with clinical findings to make accurate diagnoses. Students will also learn about the limitations and potential pitfalls of different imaging techniques and when to use additional imaging modalities. The course will foster interactive and collaborative learning to ensure that students are well-equipped to confidently diagnose and manage various bone diseases by the end of the course.

### Texts

- Diagnostic imaging Orthopaedics (Stoller)
- Radiology Assistant Educational site of the Radiological Society of the Netherlands by Frank and Robin Smithuis - https://radiologyassistant.nl/
- US of MSK system – Springer (Bianchi, Martinoli)
- A-Z of Musculoskeletal and Trauma Radiology – Murray, Holmes, Misra – Cambridge

## INDUSTRIAL BIOENGINEERING

**Credits: 1 CFU**

### Objectives

This part of the course provides a summary of the main equipment and technologies used in biomechanics for the evaluation of reliability and functionality of prostheses for the musculoskeletal system in contact with bone. Students will get an overview of available techniques and will learn how to plan an experimental activity to test prostheses.

The main objectives of the course are:

- Description of the main design requirements needed for a bone prosthesis.
- Description of numerical and experimental techniques used for the evaluation of the fulfilment of the main design requirements.
- Description of the techniques used to evaluate test results.

Knowledge and understanding: aims, methods and technologies for joint prosthesis reliability evaluation (testing machine, strain sensors, joint simulators, numerical simulators) (DD1).
Applying knowledge and understanding/Making judgments: to identify the more adequate procedure and experimental setup to test a bone prosthesis (DD2).
Learning skills: identifying design requirements, designing experimental setup, defining test protocol, analysing test results

### Prerequisites

Knowledge of anatomy and physiology of the musculoskeletal system. Basic concepts of biomechanics of joints.

## Contents

**1. Experimental and numerical orthopaedic biomechanics**
1.1. Testing procedure on implants and prostheses
    1.1.1. In vitro testing
    1.2.2. In silico testing
    1.1.3. In vivo load measurements on implants
1.2. Joint simulators
    1.2.1 Hip simulator
    1.2.2 Knee simulator
    1.2.3 Pelvis simulator
1.3 Experimental setup design
1.4 Result evaluation and reporting

## Teaching Methods

The course is organized with lessons where the students will learn how different equipments and technologies can be used for prosthesis functional evaluation. Students are encouraged to actively participate the lectures with questions and comments.

## Texts

- B. Innocenti, F. Galbusera, Human Orthopaedic Biomechanics: Fundamentals, Devices and Applications, Editor: Elsevier Science Publishing Co Inc

**NEUROPSYCHIATRIC AND REHABILITATION NURSING SCIENCES**
**Credits: 1**

**Objectives**
For several years Bioengineering has been involved in developing technologies to improve functional evaluation and rehabilitation plannings addressed to subjects with motor impairments. These advancements push physicians and physiotherapists to develop skills about the use of technologies in clinical practice.
In order to reach this goal, clinicians involved in rehabilitation field need to move on from preserving traditional and non-technological models and must consider how the use of these technologies can integrate functional assessment or therapeutic exercise to promote motor learning in subjects with motor impairments.
The objective of this course is to introduce theory, rationale, and applications of technologies used in motor rehabilitation.

**Prerequisites**
Knowledge of physics, and neurophysiology are suggested.

**Contents**
**Acquisition and interpretation of electromyographic signals in subjects with motor impairments.**
This lesson will present the methodologies for acquisition, analysis, and interpretation of surface electromyographic (sEMG) signals in subjects with motor impairments due to neurologic or musculoskeletal disorders. Moreover, different kinds of myoelectric signals acquisition (bipolar sEMG, array or matrix of electrodes etc..) and their integration with other instrumental devices during the execution of functional tasks will be presented. Finally, the adaptation of rehabilitative exercises based on sEMG data will be underlined.

**Instrumental analysis of motor performance 1**.
This lesson will present the use of dynamometers for the assessment of joint torques in rehabilitation of subjects with motor impairments. A particular emphasis will be put on the arthrogenous muscle inhibition measurement in patients with articular disorders, and on the relevance of this impairment in clinical practice.

**Instrumental analysis of motor performance 2.**
This lesson will present the use of optoelectronic systems and force platforms for the assessment of joint kinematic and centre of pressure displacement in subjects with musculoskeletal and neurological disorders. Moreover, the analysis of helical axes displacement acquired through optoelectronic system in subjects with knee and shoulder disorders will be also presented.

**Integration between robotics and therapeutic exercise in rehabilitation plannings.**
This lesson will present the most used robots and exoskeletons adopted in rehabilitation to promote functional recovery of locomotion and upper limb mobility in subjects with motor impairments due to neurological diseases. A particular focus will be put on the integration between robotics and therapeutic exercise, and on motor learning principles deriving from this integration. Their presentation will be anticipated by the introduction of the state of the art about their efficacy.

**Integration between virtual reality and therapeutic exercise in rehabilitation plannings.**
This lesson will present virtual reality (VR) systems as a valid addition to therapeutic exercise able to provide a positive motor learning experience and enhance subjects' engagement and motivation. The effects of multisensory stimulation administration in subjects with musculoskeletal and neurological disorders will regard the use of augmented reality and immersive virtual reality systems. Moreover, VR interventions integrated with additional biosensors such as Inertial Measurement Units (IMUs), force sensors, sEMG, and robotics will be also presented. Presentation of VR systems will be anticipated by the introduction of the state of the art about their efficacy.

**To promote motor learning by action observation training**
This lesson will present the application of action observation training (AOT), consisting of a multi-sensory approach that works by activating the mirror neuron system (MNS) of the brain. AOT commonly includes the observation of action proposed by videos, followed by action execution or motor imagery of the observed actions. The effects of this approach on motor learning of subjects with motor impairment have been described in several scientific articles. A particular focus

will be put on the neurophysiological rationale of this approach, and on the characteristics of videos proposed to subjects with motor impairments.

**Teaching Methods**

The course is organized with frontal lessons. Moreover, students will exploit the possibility to attend the Physiotherapy Unit of Humanitas Hospital (Laboratory of movement analysis or technologies room) in order to observe the application of contents presented during the lessons.

**Texts**

Slides of the lessons and selected scientific articles delivered during the lessons period.

**ASSESSMENT**

The final test will consist of multiple-choice questions (with only one correct answer) on all the topics covered during the course and present in the syllabus. The final mark will be proportional to the number of correct answers.