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Devices for NeuroControl and NeuroRehabilitation

F.Cortés - J.Ricart
LEITAT
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The work has been performed in the project DENECOR, co-founded by grants from Spain,UK, The Netherlands, Germany, Austria, Italy and Czech Republic and the ENIAC Joint Undertaking.

DENECOR Targets

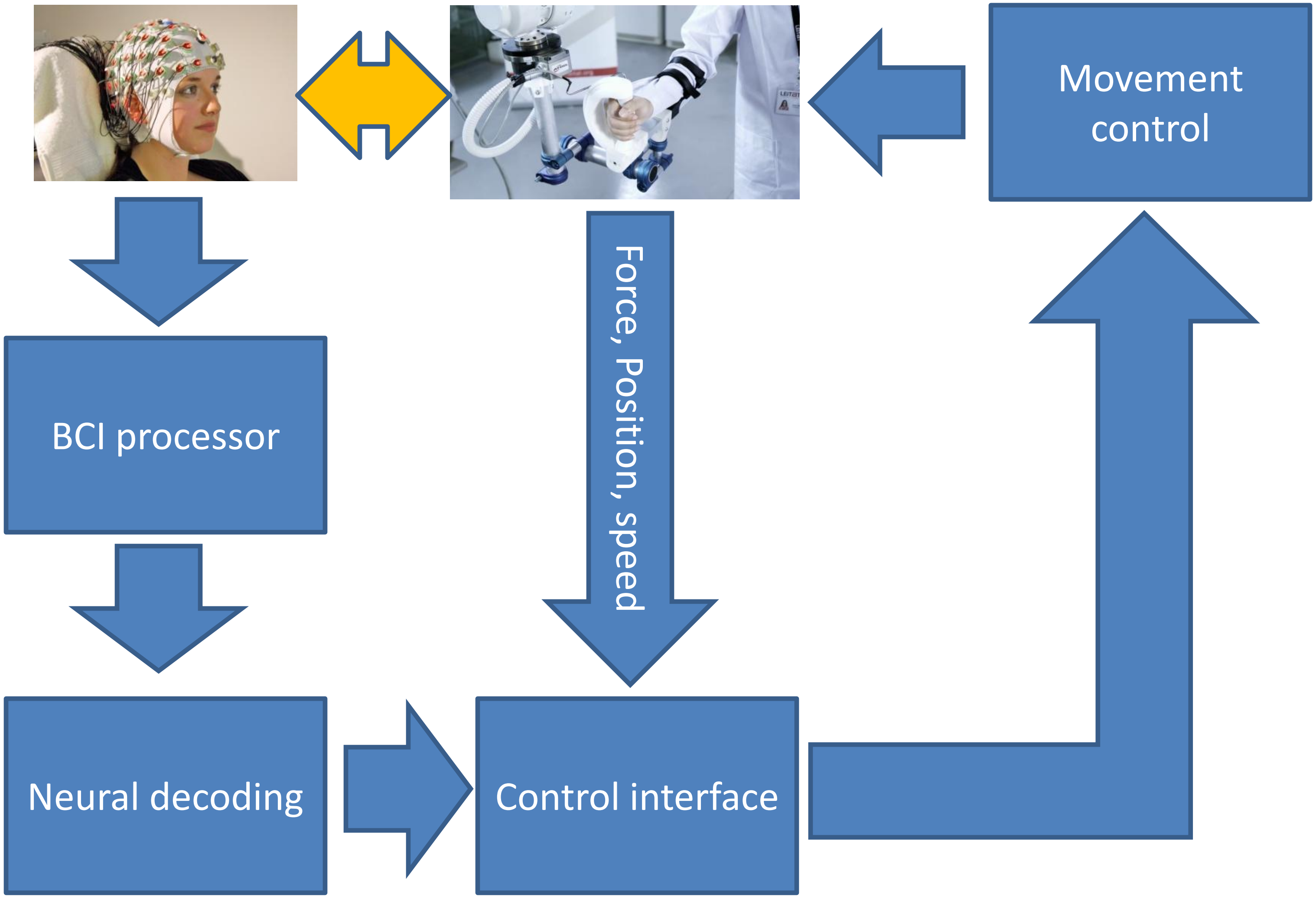
•Demonstration of an MRI compatible Transcranial Magnetic Stimulator (TMS) with focused spatial localization. This requires distribution and miniaturization of power electronics.

•Development of new sensor and packaging technology for invasive and non-invasive neural sensing (e.g. EEG), compatible with the MRI and TMS environment. The demonstration includes connection to neuro-modulation and neuro-rehabilitation devices.

•Demonstration of an MRI-guided endoscopic system with integrated ultra- sound system, based on innovative Capacitive Micromachined Ultrasound Transducers (CMUT), miniaturization of electronics and 3D packaging.

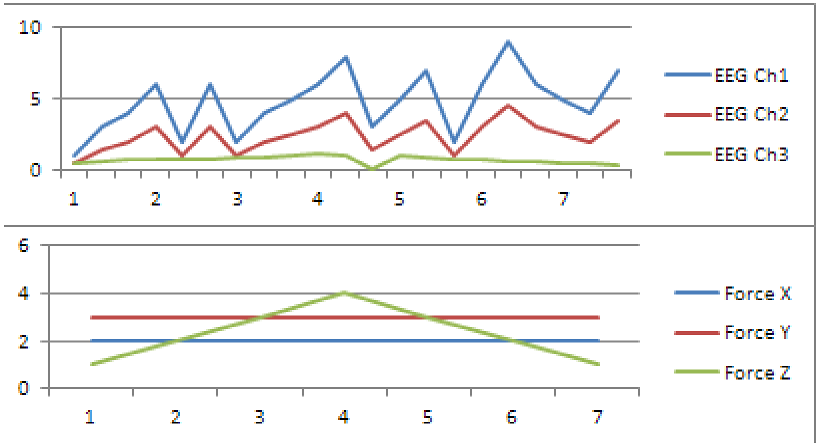
http://www.denecor.info/en/objectives/

DENECOR neuro-rehab overview



DENECOR neuro-rehab overview

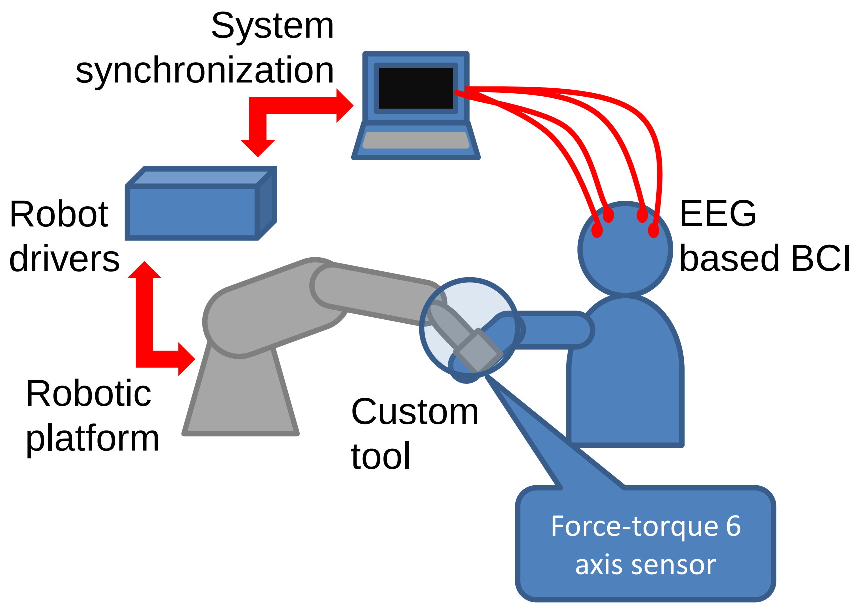
Rehabilitation devices connected to the invasive electrical registration of brain signal.



<u>Objectives:</u>

To develop a flexible neuro-rehabilitation platform based on BCI and robotics to allow patient monitoring and haptic feedback during exercises. This system consists of:

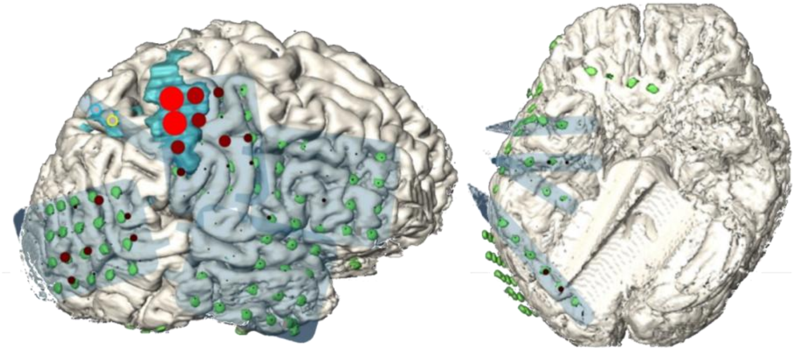
- A safe robotic platform allowing multiple rehabilitation exercises
- A robot tool designed for specific application (upper limb) according to user needs.
- An EEG acquisition system to be used as BCI during rehabilitation exercises.
- A processing system for signal synchronization between both elements



Example EcoG analysis

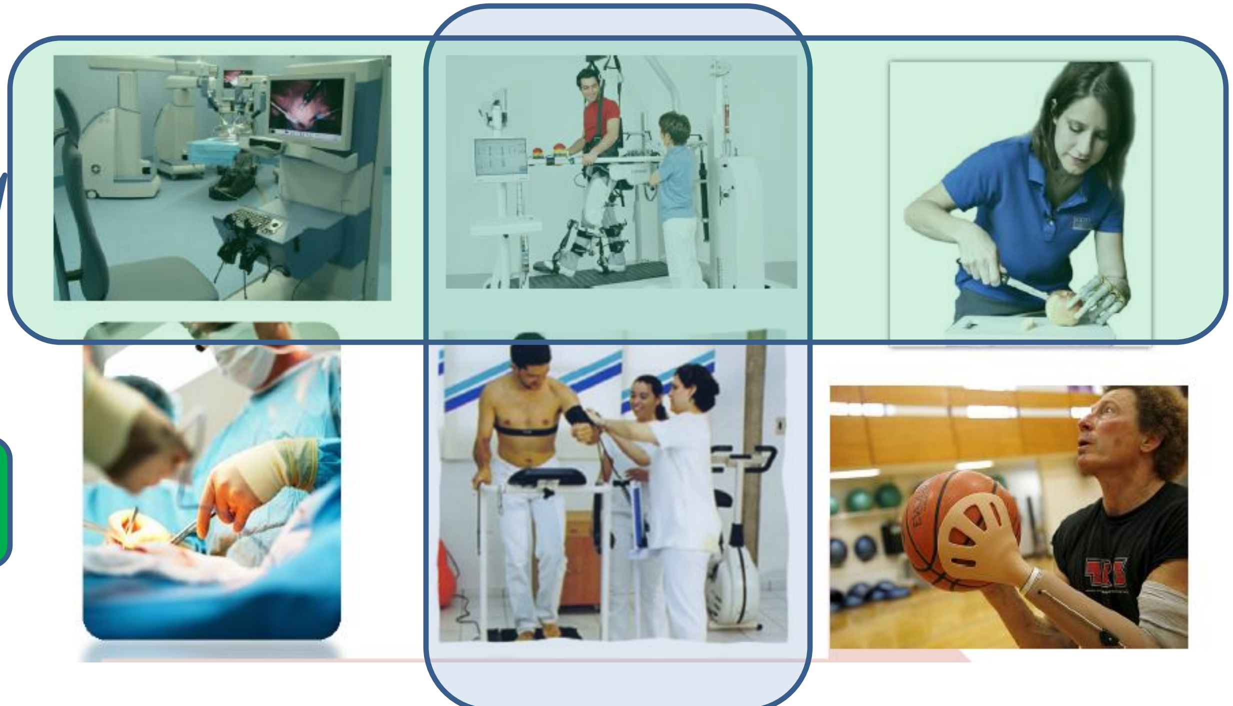
➢ Developments (GTEC)

- New procedure for recording of cortico-cortical evoked potentials (CCEP)
- Application on EEG rehabilitation (under involvement of LEITAT robot)
- Brain-Computer Interface (BCI) capable to acquire and process electrocorticographic signals (ECoG), to classify hand gestures.
- Test using hand position detection (rock, paper, scissors).



Finger tapping

DENECOR reahabilitation

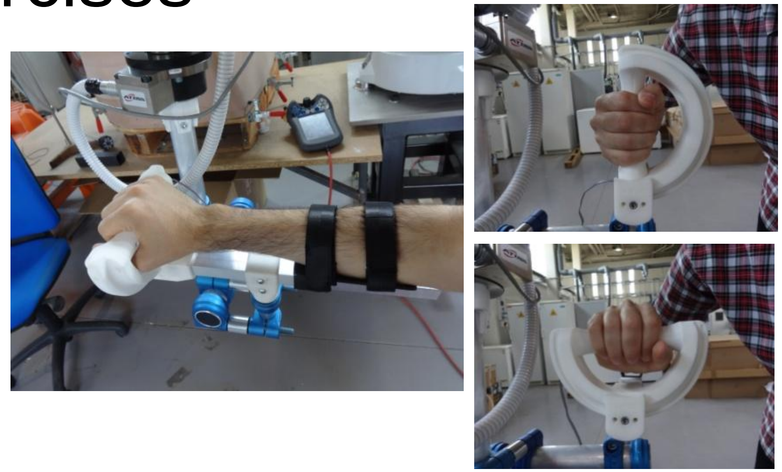


Automation& measurement

Rehabilitation phase

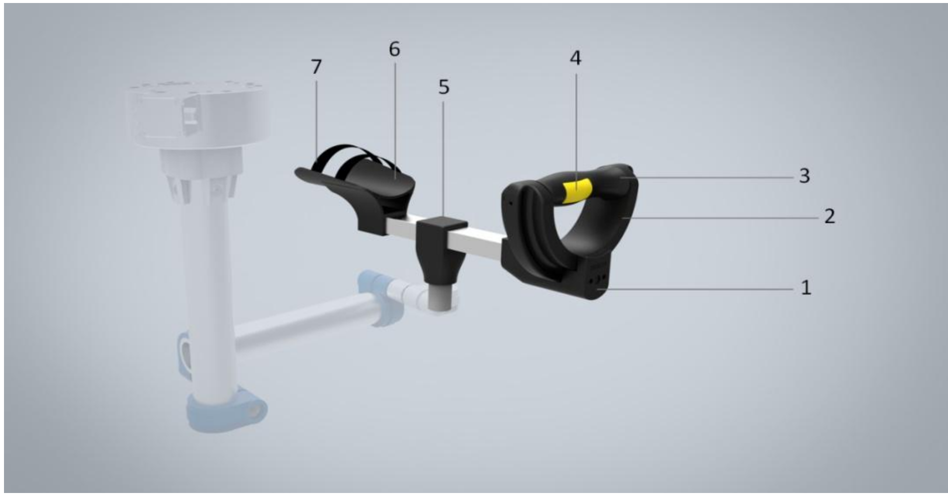
Goals:
- Easy to setup with direct movement recording
- Adaptable to many exercises changing the tool (orthesis)
- Scalable to different force levels (2000 N with bigger units)
- BCI feedback to change exercise parameters
- Easy speed, force, position measurements

Orthesis for upper limb exercises



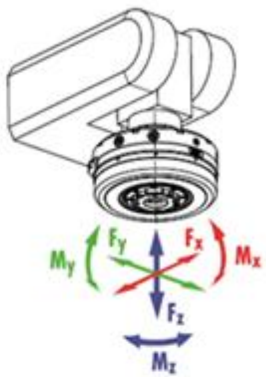
- Specific robot tool for upper limb rehabilitation exercises has been designed.
- This tool integrates emergency actuators according to defined safety measures.

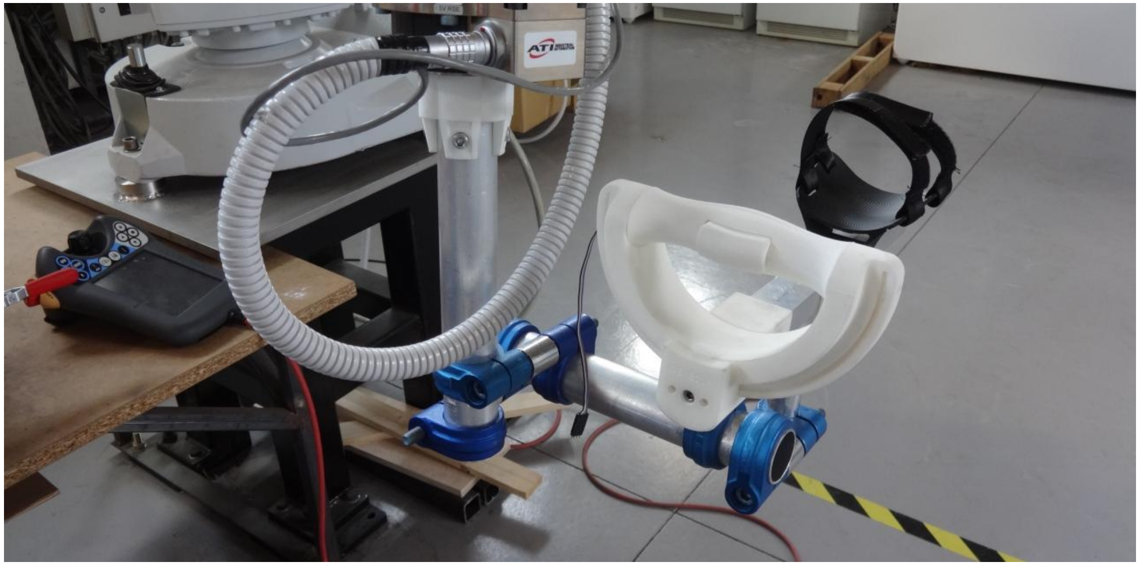
1. Handle Base
2. Rotational Handle Support
3. Handle
4. Safety Button
5. Structure link
6. Arm support
7. Velcro Strips
8. Safety button connector (not shown)



Technical status & achievements

Video





- System includes a force sensor for safety (force and speed limitations) and to interface with the user during the exercises
- Mechanical and electrical design to hold the patient arm with a safety pushbutton
- Software creates exercises easily and interfaces with the EEG system

Technical status & achievements

ROLES:

- The patient: is the person who performs exercises, actively connected to a monitoring EEG system.
- The medical assistant(s): person(s) with enough medical knowledge to define the exercises, movements, parameters, EEG, etc…
- The technical assistant: is a person with enough technical knowledge to setup and configure the robotic rehabilitation system.

FUNCTIONS:

- Path recording: Allows easy recording of the movement for a specific exercise.
- Passive execution: Repeats the movement at a percentage of the recorded speed. Patient is passive, robot drags patient to each position without his/her participation.
- Haptic execution: Robot has to move the robot along the path recorded, by exerting a force to move the robot.

Procedures

PATH RECORDING

Video

1. Patient arm is fixed on the system. He/she should push safety button firmly.
2. The technical assistant (me) initiates path recording.
3. Robot enters recording mode and user can move the robot in any direction with very low effort. In fact, robot moves by itself to that direction.
4. Robot is monitoring the movement and stores all movements and speed.
5. The system stops recording automatically if the patient keeps the same position more than 5 seconds.

PROCEDURES

Video

PASSIVE REPLAY

1. Patient uses passive execution when he/she needs to move his/her arm without exerting any force. In any moment, patient can stop the movement opening the fist and releasing the safety button.
2. User is linked to de robot system placing his arm on the mechanical interface. Patient has to push firmly the safety pushbutton and keep it in this position.
3. Technical assistant initiates the exercise.
4. Robot enters in position run mode, with a maximum speed of 250 mm/s, limited for safety reasons. Robot repeats the movement at the exact same speed as it was recorded and finishes at the end position.
5. Speed of the movement can be changed (up and down) according to a parameter received from the BCI interface. Other signals (like heart beat rate, sweating or any physiological measure) can be used to control the exercise.

PROCEDURES

Video

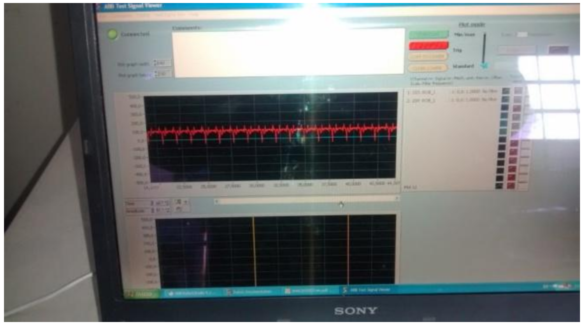
HAPTIC / FORCE REPLAY

1. Patient uses haptic or force active execution when he/she needs to move his/her arm pushing with a certain force. Robot doesn't move, unless the user exerts a certain force level.
2. User is linked to de robot system placing his arm on the mechanical interface Patient has to push firmly the safety pushbutton and keep it in this position.
3. Robot remains in position, unless patient pushes with a force higher than a certain force threshold and towards the exact direction as it was recorded. Robot refuses the movement if patient tries to move to another direction or backward. For simplicity, force is tangent to the movement, but it can be in any directions along the path.
4. Force can be changed to a percentage (up and down) according to a parameter received from the BCI system or any other relevant physiological measurement.

Actual prototype

- BCI system will send hand position detected from a real (recorded) BCI signal. Hand position is visible on PC screen.
- Alternatively, we can send a specific hand position to the robot to simulate the BCI signals.
- During passive replay, speed is changed depending on hand position.
- During force replay, required force to move the robot changes according to hand position (open = easy, closed=hard, V position = harder).

In addition, we can visualize force signals on a PC using a signal recorder software.



Advantages

Protocol standardization

Medir/sensorizar

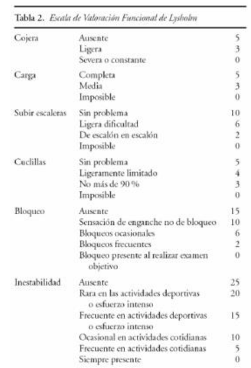
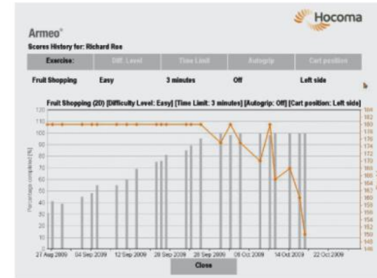
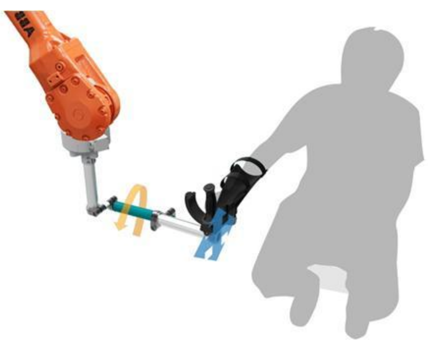


Tabla 2. *Escala de Valoración Funcional de Lysholm*		
Cojera	Ausente	5
	Ligera	3
	Severa o constante	0
Carga	Completa	5
	Media	3
	Imposible	0
Subir escaleras	Sin problema	10
	Ligera dificultad	6
	De escalón en escalón	2
	Imposible	0
Cuclillas	Sin problema	5
	Ligeramente limitado	4
	No más de 90 %	3
	Imposible	0
Bloqueo	Ausente	15
	Sensación de enganche no de bloqueo	10
	Bloqueos ocasionales	6
	Bloqueos frecuentes	2
	Bloqueo presente al realizar examen objetivo	0
Inestabilidad	Ausente	25
	Rara en las actividades deportivas o esfuerzo intenso	20
	Frecuente en actividades deportivas o esfuerzo intenso	15
	Ocasional en actividades cotidianas	10
	Frecuente en actividades cotidianas	5
	Siempre presente	0



Objective measurements and progress



Cost & simplicity vs special devices

Patient motivation and engagement

Drawbacks

Clinical acceptance: When? How?

Measurements interpretation vs patient’s sensations

Cost vs standard treatments

Thank you for your attention

Francesc Cortes
fcortes@leitat.org

Jordi Ricart
jricart@leitat.org

+34 937882300