



## "Basics in motion analysis "

Milan, September 10-21 Sept 2007

Postural control  
Manuela Galli

September 11th 2007



### Introduction

- 🌐 No universal definition of posture and balance
- 🌐 No agreement on the neural mechanisms underlying control of posture and balance
- 🌐 Postural control emerges from interaction of **individual** with **task** and **environment**
- 🌐 Postural control system is complex interaction of musculoskeletal and neural systems



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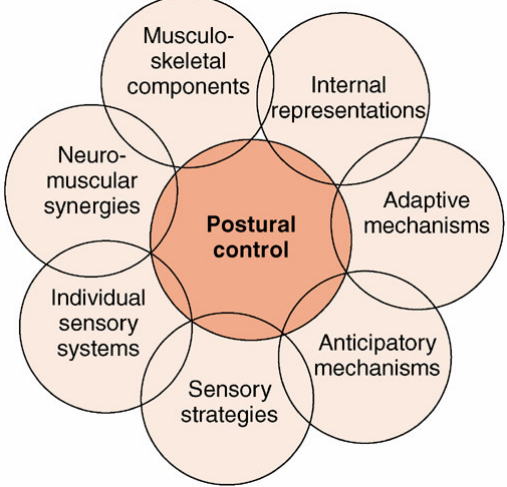
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### Postural Control Requirements **Vary with the Task and Environment**




- Specific orientation and stability requirements vary according to task and environment
- Strategies used to accomplish postural control must adapt to varying task and environmental demands


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The diagram illustrates the components of postural control as a central orange circle labeled "Postural control" surrounded by seven overlapping light orange circles. The components are: Musculo-skeletal components, Internal representations, Adaptive mechanisms, Anticipatory mechanisms, Sensory strategies, Individual sensory systems, and Neuro-muscular synergies.




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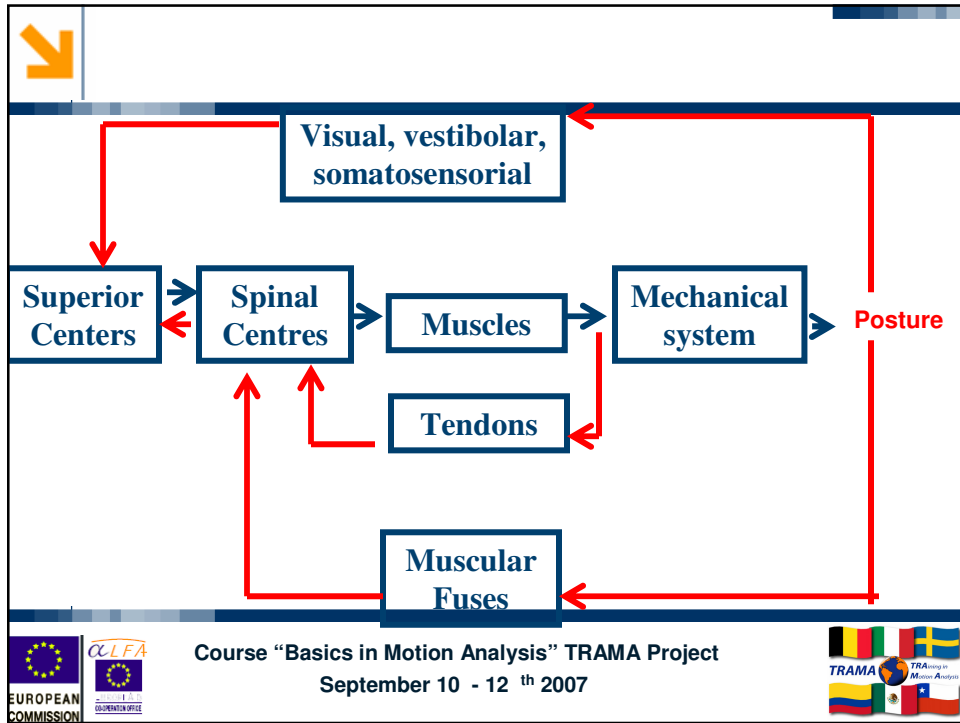
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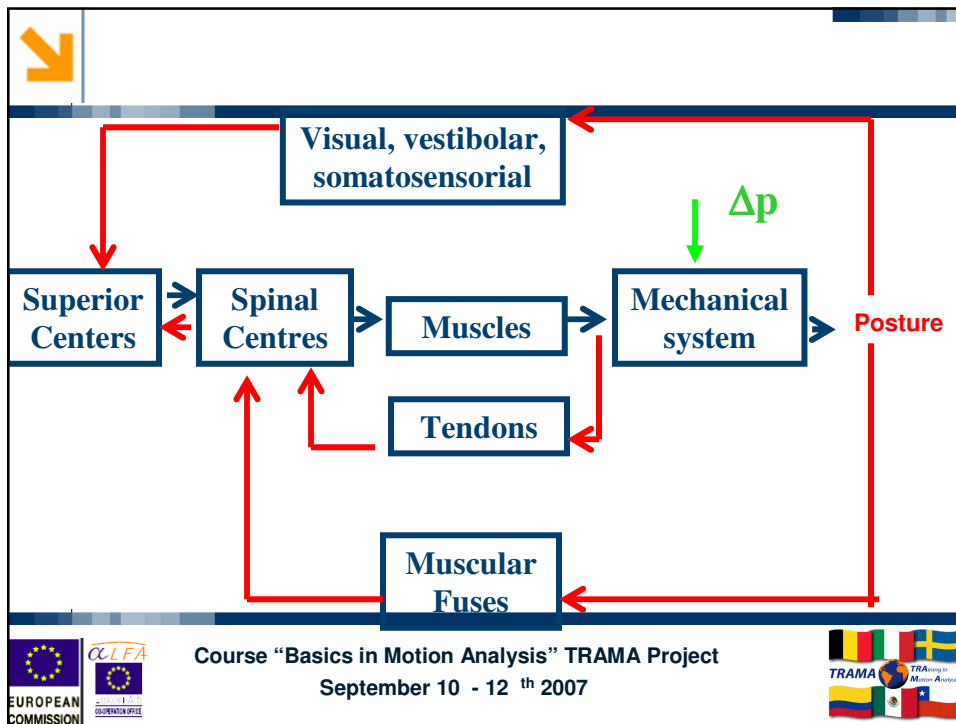


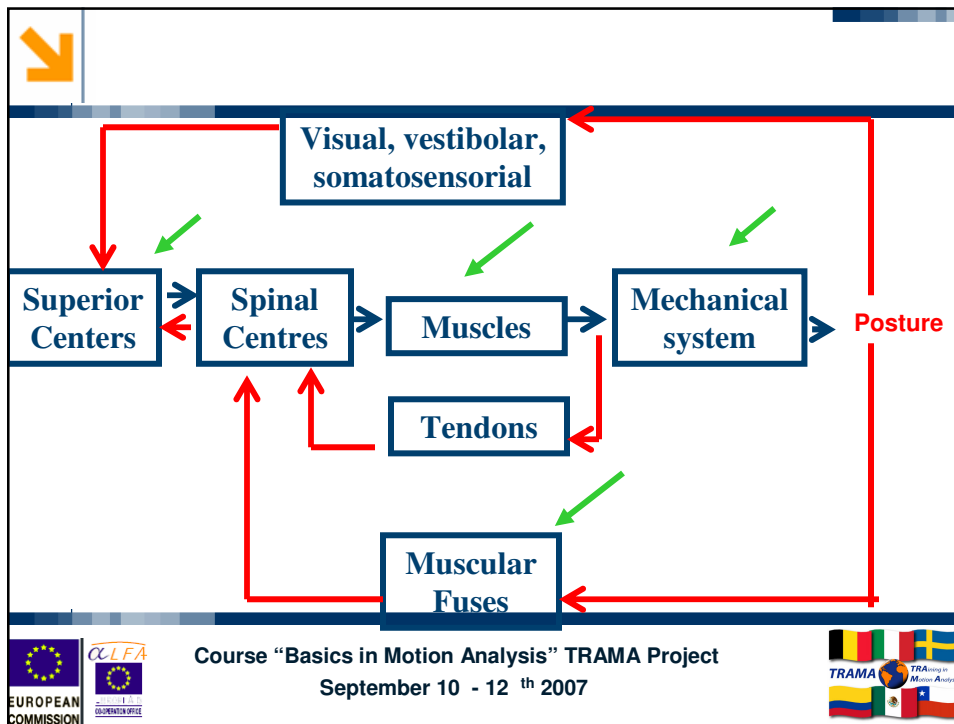
## Defining Systems for Postural Control

-  Musculoskeletal components
-  Neural components

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### Defining Postural Control

- Postural control involves controlling body's position in space
- Postural orientation — ability to maintain appropriate relationship between body segments and between the body and environment for a task
- Postural stability — ability to control COM in relationship to the base of support

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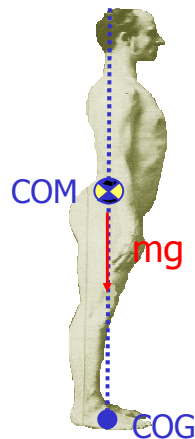


## Postural Control

- Center of control (COM) is point at the center of the total body mass,
- Center of pressure (COP) is center of distribution of total force applied to supporting surface
- Relationship between COM and COP provides better insight into stability than either COP or COM alone



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**COM (Center of Mass):** Center of control is point at the center of the total body mass,  
The projection on the ground is the Center of Gravity (**COG**)





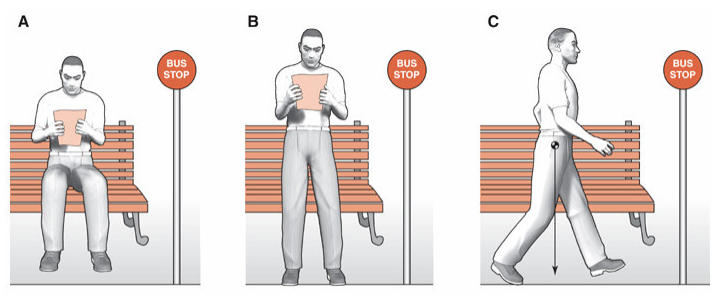
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**COP (Center of Pressure):** it is the point of application of ground reaction force . It is computed as a mean value of pressure over the contact area with the ground.


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**A** COG projected within BOS

**B** COG projected within BOS

**C** COG projected outside of BOS

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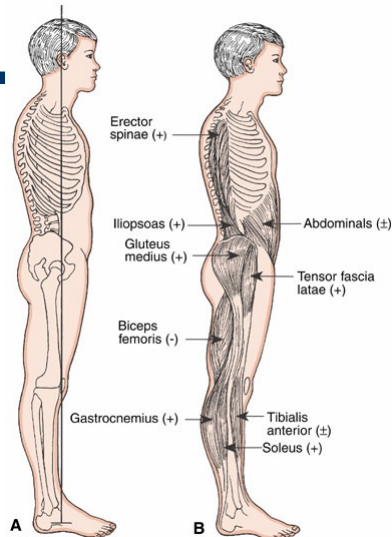


## Motor Control of Quiet Stance

- Alignment
- Muscle tone
- Postural tone



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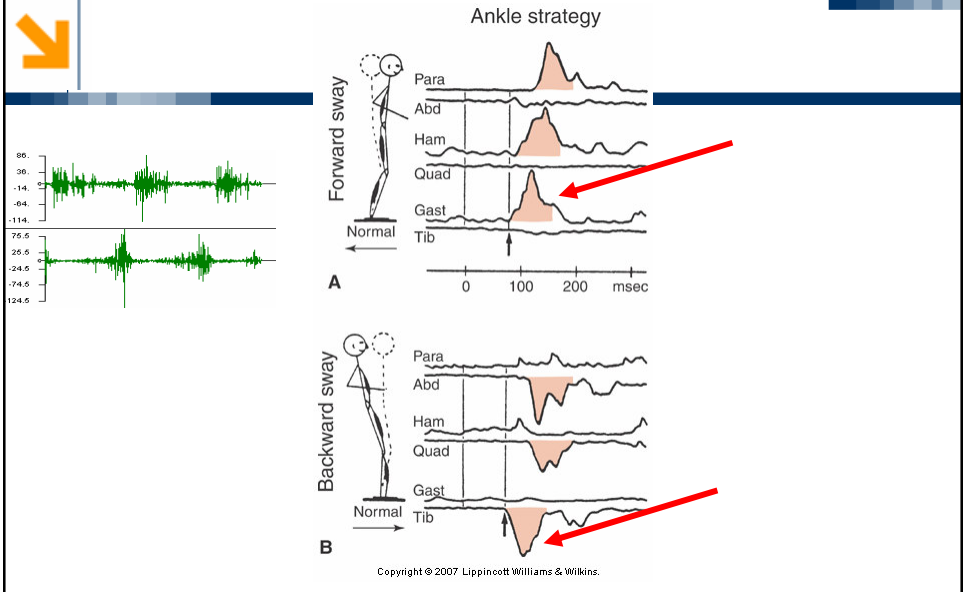





**Anteroposterior Stability**

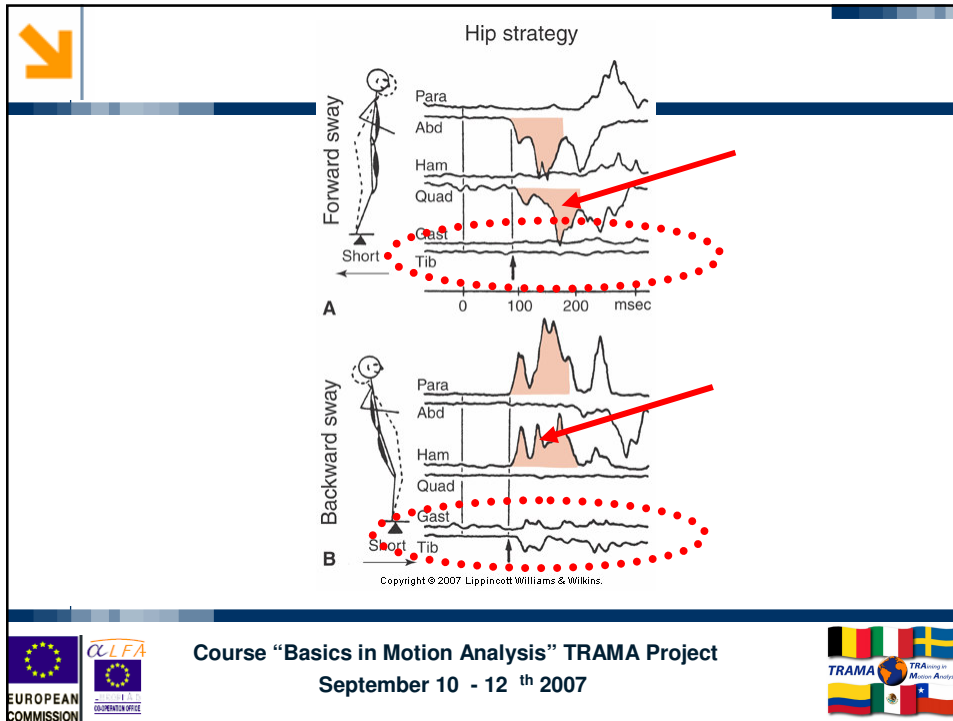
- 🇪🇺 Ankle strategy
- 🇪🇺 Hip strategy
- 🇪🇺 Stepping strategy



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**Ankle strategy**





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## Mediolateral Stability

- Alternative strategies used to recover stability in mediolateral direction
- Muscle patterns organized in a proximal-to-distal direction



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## Multidirectional Stability

Continuum of response patterns that control stability in the 360-degree continuum of possible perturbation directions

- With the new view each muscle can belong to more than one synergy; within a synergy an individual muscle has unique or fixed weighting factor to represent level of muscle activation


Two differences between the traditional way of viewing synergies and the new one that is associated with computational analysis




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## Adapting Motor Strategies

 Subjects without neural pathology can shift relatively quickly from one postural movement strategy to another

 Repeated exposure to a given postural task causes subjects to refine their response characteristics to optimize response efficiency



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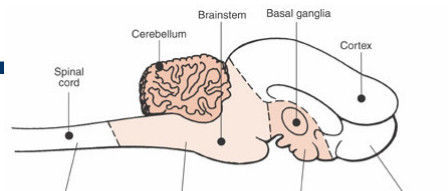


## Neural Subsystems Controlling Postural Orientation and Stability

- Postural stability is not organized at the spinal level, but is controlled by higher centers, such as the brainstem cerebellum



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Spinal preparation	Brainstem level	Basal ganglia/cerebellum	Intact system
Ground reaction forces for orientation present though diminished	Controls level of postural tone in combination with cerebellum	<i>Cerebellum</i> Control of adaptation — abilities to modify postural muscle amplitude in response to changing task and environmental conditions	Adaptable postural control system to meet the goals of stability and orientation in any environment
Tonically active extensor muscle for antigravity support for postural orientation	Circuits for automatic postural synergies (hypothesized)	<i>Basal ganglia</i> Control of postural set—ability to quickly change muscle patterns in response to changing task and environmental conditions	Visual contribution to postural control
No lateral stability	Vestibular contributions to postural control		
Somatosensory contributions to postural control			

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## Perceptual Systems in Postural Control




 In order to know *when* and *how* to apply restoring forces, the CNS must have an accurate picture of *where* the body is in space and whether it is stationary or in motion



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## Senses Contributing to Postural Control







-  Visual inputs
-  Somatosensory inputs
-  Vestibular inputs





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Sensory condition	1	2	3	4	5	6
Sensory information						
Accurate	Vest Vision Somato	Vest Somato	Vest Somato	Vest Vision	Vest	Vest
Inaccurate	None	None	Vision	Somato	Somato	Vision Somato

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Abnormal Postural Control








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 **Introduction**

-  Balance is critical to independence in daily life activities
-  Loss of stability has a profound impact on the daily life of individuals with neurologic pathology

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 **Falls Following Neurologic Pathology**

-  Prevalence varies by diagnosis
-  Prevalence varies by setting

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## Risk Factors for Falls in Neurologic Populations

- 🇪🇺 Acute stroke
- 🇪🇺 Chronic stroke
- 🇪🇺 Parkinson's disease
- 🇪🇺 Multiple sclerosis



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## Problems in the Motor Components of Postural Control

Motor components include both musculoskeletal and neuromuscular systems



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## Motor Coordination Problems

Neurologic deficits influence the coordination of muscles into postural synergies

- Sequencing problems
- Delayed activation of postural response
- Problems modifying postural control



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## Sequencing Problems

Reversals in the orderly recruitment of muscles

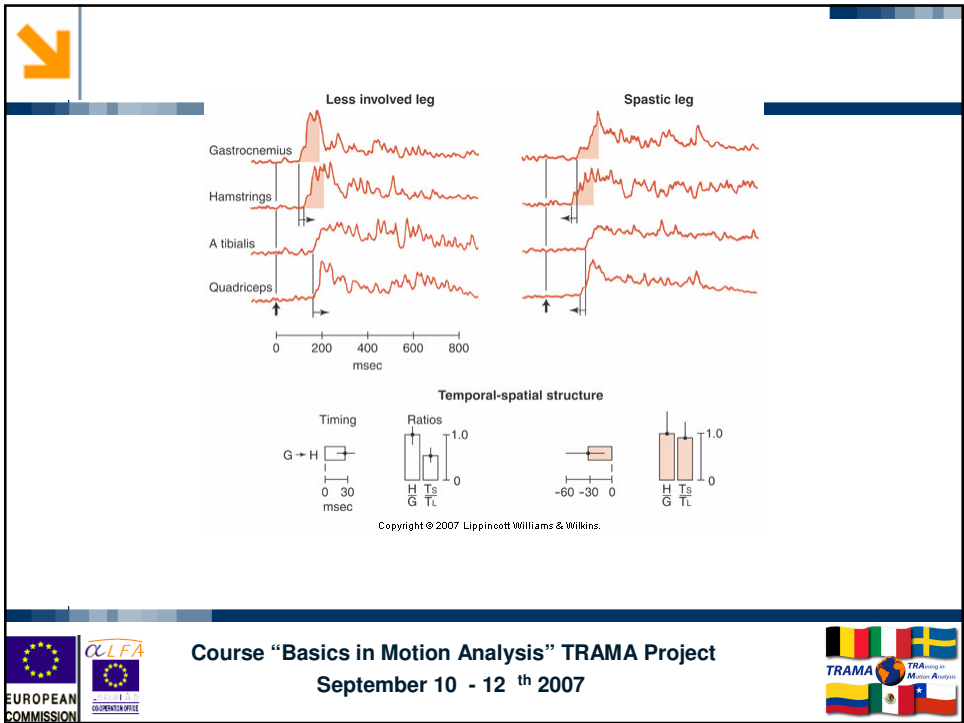
Delayed recruitment of proximal synergistic muscles

Coactivation of antagonist muscles

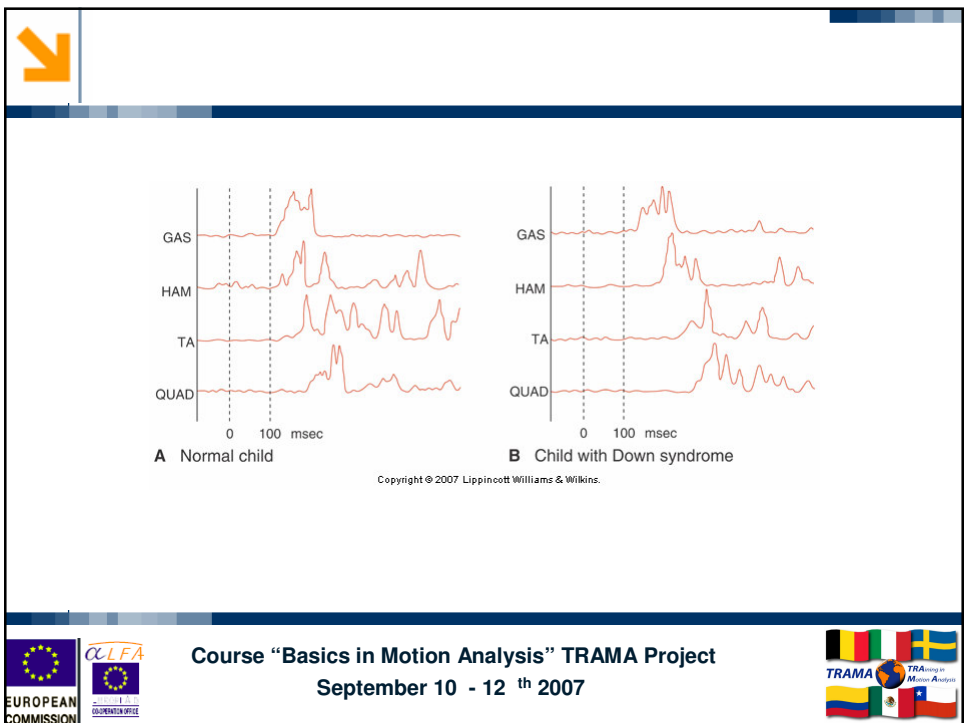


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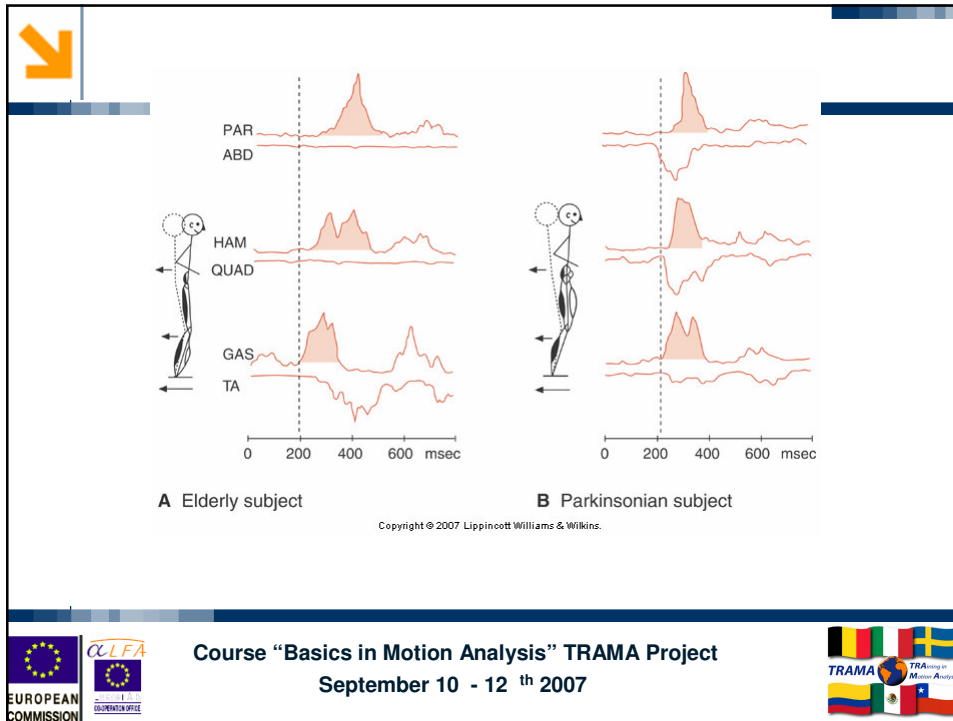


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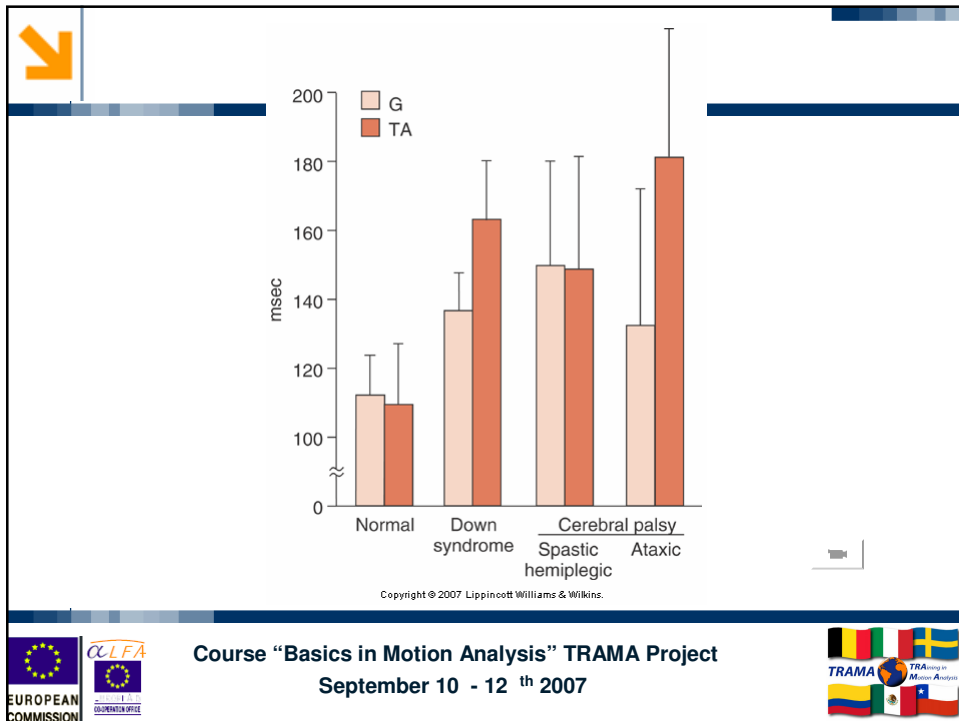
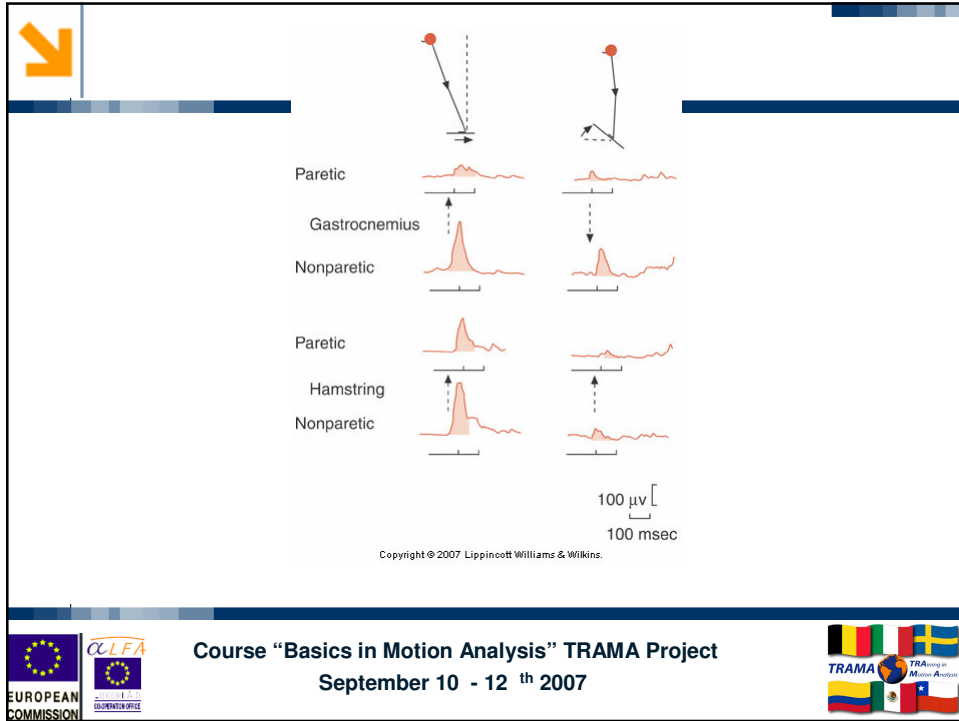
## Delayed Activation of Postural Responses

Significant delays in onset of postural activity reported in developmental abnormalities



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## Musculoskeletal Contributions to Coordination Problems

- With a central nervous system (CNS) lesion, musculoskeletal disorders develop most often secondary to immobility and restricted movement
- Musculoskeletal problems affecting postural control
  - Alignment
  - Constraining movement at a joint
  - Loss of ROM/flexibility



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## Alignment




- Cerebral palsy
- Cerebral vascular accident
- Elderly






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### Constraining Movement at a Joint

-  Ankle-foot orthoses (AFOs)
  -  Solid
  -  Spiral or hinged



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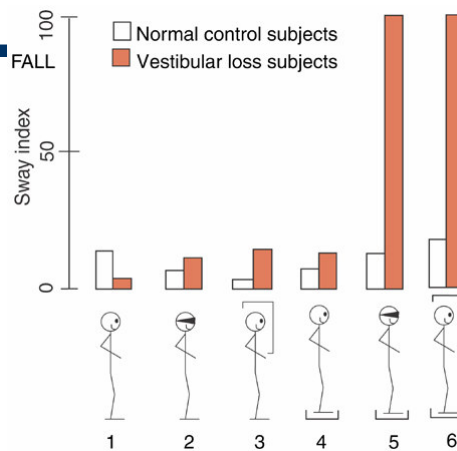


## Sensory Disorders

- 🇪🇺 Affect the ability to adapt sensory inputs to changes in task and environmental demands
- 🇪🇺 Prevent development of accurate internal models of the body for postural control



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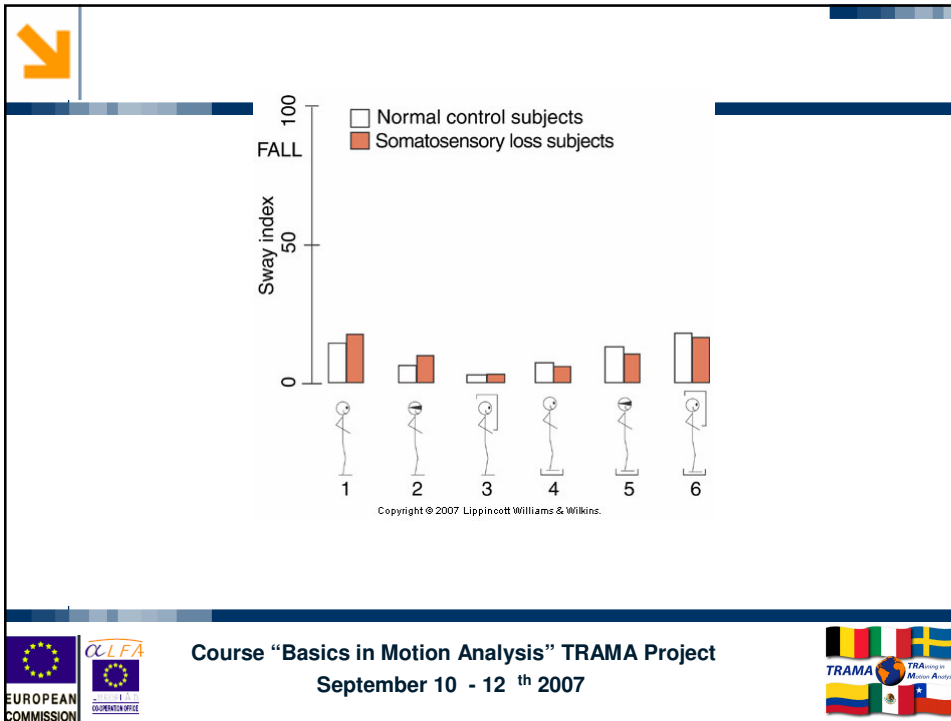
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## Impaired Cognitive Function and Postural Control

Research is focusing on

- Impact of cognitive load
- Forms of dementia



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## Postural Control in Persons with Dementia

Motor coordination

Sensory organization



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## Adults with Neurologic Pathology

Acute and chronic stroke

- Voluntary movements in trunk
- Anticipatory postural activity in trunk and limbs



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## Pediatric Populations

Seated postural control

- Cerebral palsy
- High-risk infants with developmental delays



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## Experimental evaluation of Posture



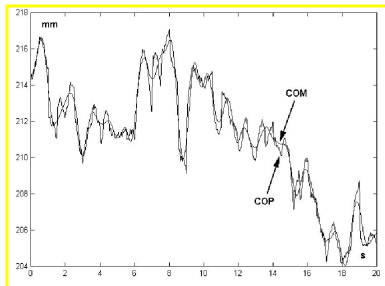
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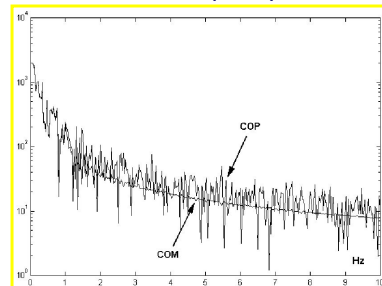


- ✓ Time domain analysis
- ✓ Frequency domain analysis

COP e COM in time



COP e COM frequency domain



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### Modalità delle prove di posturografia:

- Barefoot
- 50-60 sec
- Open/Closed Eyes
- 3 trials
- Resting time between each trial
- if possible Kinematics, kinetics and emg

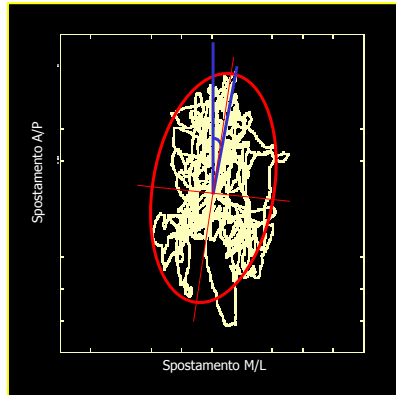


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### • STATOKINESIOGRAM or SWAY



COP A/P vs M/L

#### INDEXES:

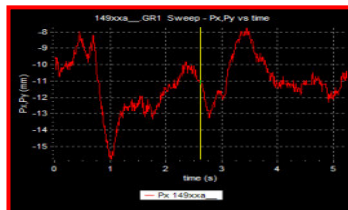
- Trajectory length
- M/L ROM
- ANT/POST ROM
- Area (ellipse)
- Angle of oscillation
- length/area



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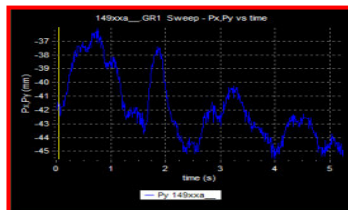
### • STABILOGRAM



A/P e M/L component of COP vs time


#### INDEXES:

- A/P e M/L ROM
- Mean excursion of A/P e M/L
- Maximal excursion AP e M/L
- Time of maximal excursion AP e M/L



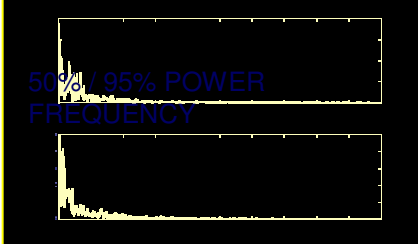
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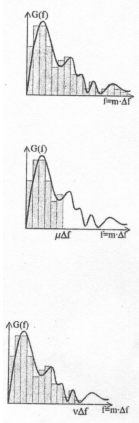






**TOTAL POWER**  $\int A_G(t) dt$  **area** **segnale**



50% / 95% POWER  
FREQUENCY











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# Practical session

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