



# **Kinematic data for disabled workstation design**

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# [ reaching and inter-joints coordination ]

- human reach in horizontal and vertical planes has been mainly estimated as arcs and areas not considering the space-time relationships among the different arm joints (Kozey, J.W. and Das, B., 2004).



# [trunk and prehension]

- trunk is treated as a component of the system of prehension.

**Grady, T.H., Davis, J. and Maghsoodloo, S., 2008.**

The effects of dynamic movement on seated reach arms. 51, 691-701



# [ knowledge on upper limb inter-joints coordination ]

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- **assessment of functional limitations and compensatory strategies of disabled;**
- MSD prevention;
- implementing virtual ergonomics models with motor program elements.

# [ subjects and controls ]

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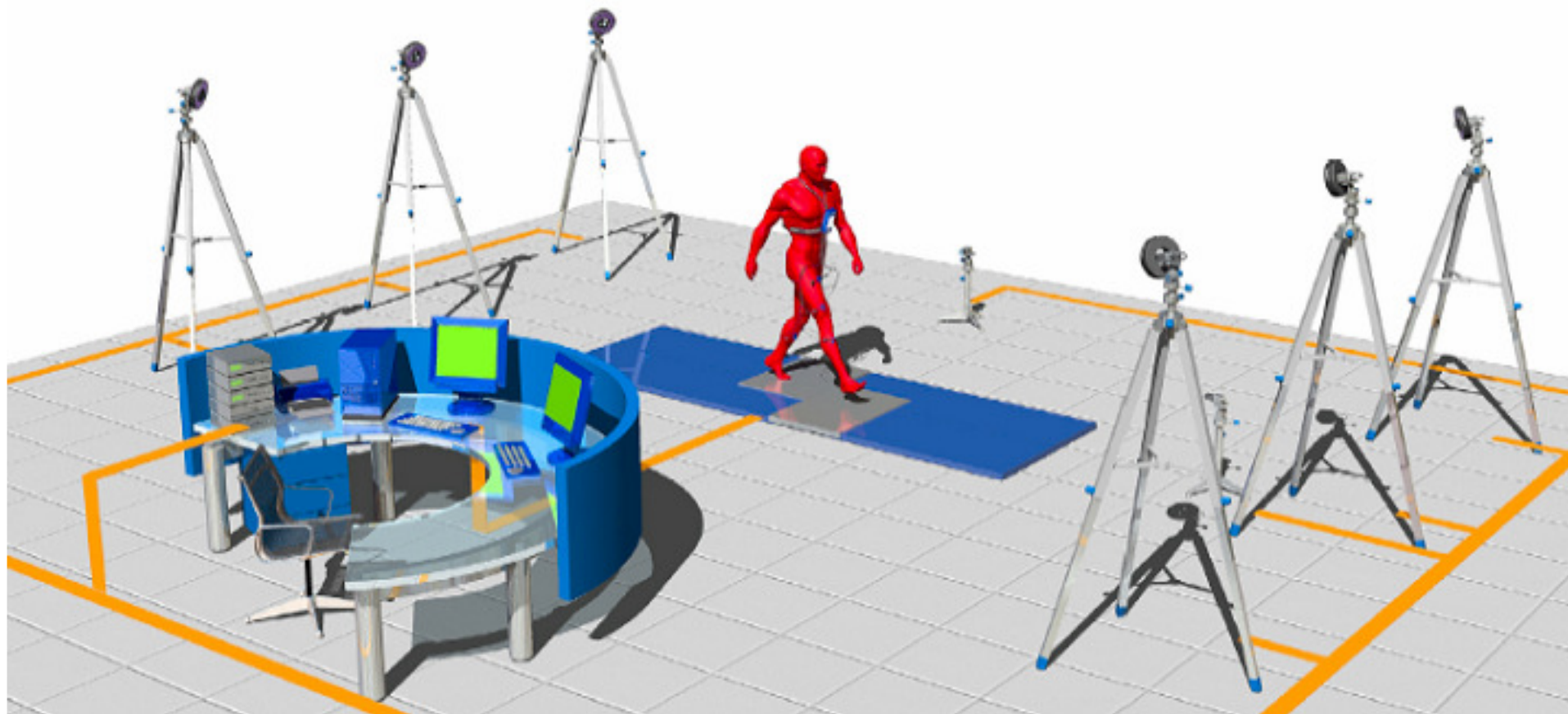
- ten right-handed patients (males, mean age  $32.9 \pm 6.9$  years, range 23–48 years) all fulfilling the clinical and electrodiagnostic criteria for BP-IT, and ten healthy, age-matched males as controls (mean age  $36.3 \pm 8.7$  years, range 25–51 years).

# [ kinematic recordings ]

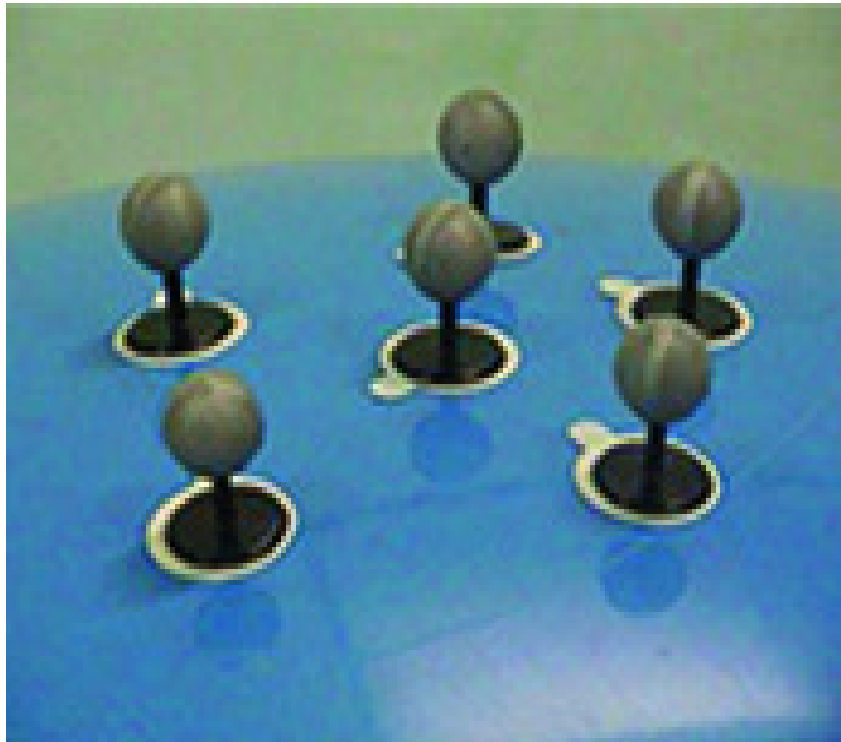
- we used an optoelectronic motion analysis system (SMART-E System, BTS, Milan, Italy) consisting of eight infra-red ray cameras to detect the movements in three-dimensional space of nine retro-reflective markers placed on the skin (Ferrigno, G., Pedotti, A., 1985).



[ the lab ]



# [ markers and infrared cameras ]



# [ Rab biomechanical model ]

- nine markers model: left and right acromion, the spinous process of the seventh cervical vertebra, the right olecranon, the right styloid ulnar and radial processes, the sacrum, and the right and left anterior superior iliac spinae (Rab et al, 2002).



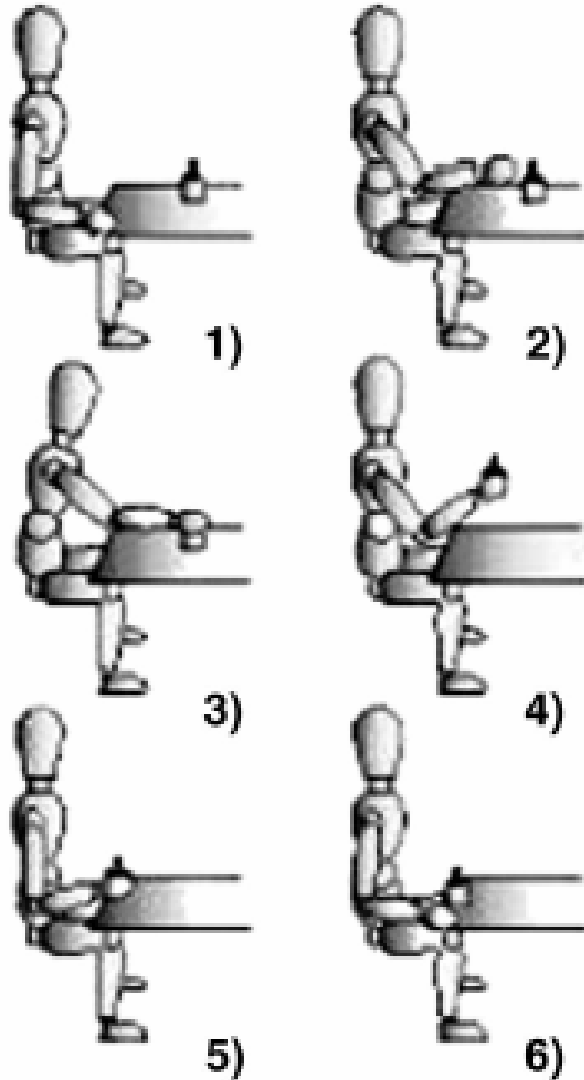
# [ experimental procedure: R&G ]

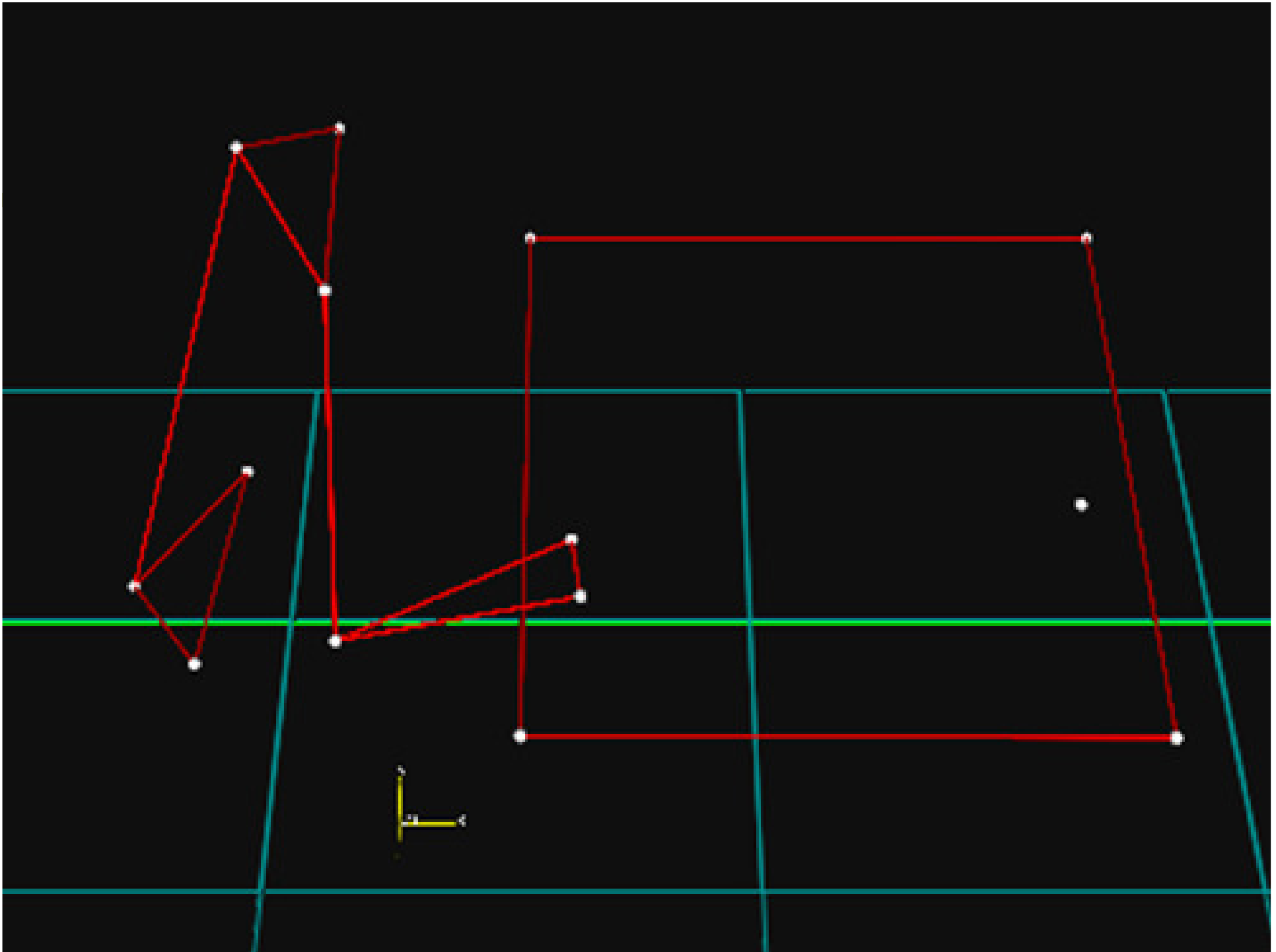
- subjects performed a movement that consisted of reaching out from the starting position, picking up a cylinder, positioned at the maximal reach estimate, and carrying it back to the starting position.

# [reaching and grasping (top)]



# [reaching and grasping (lateral)]

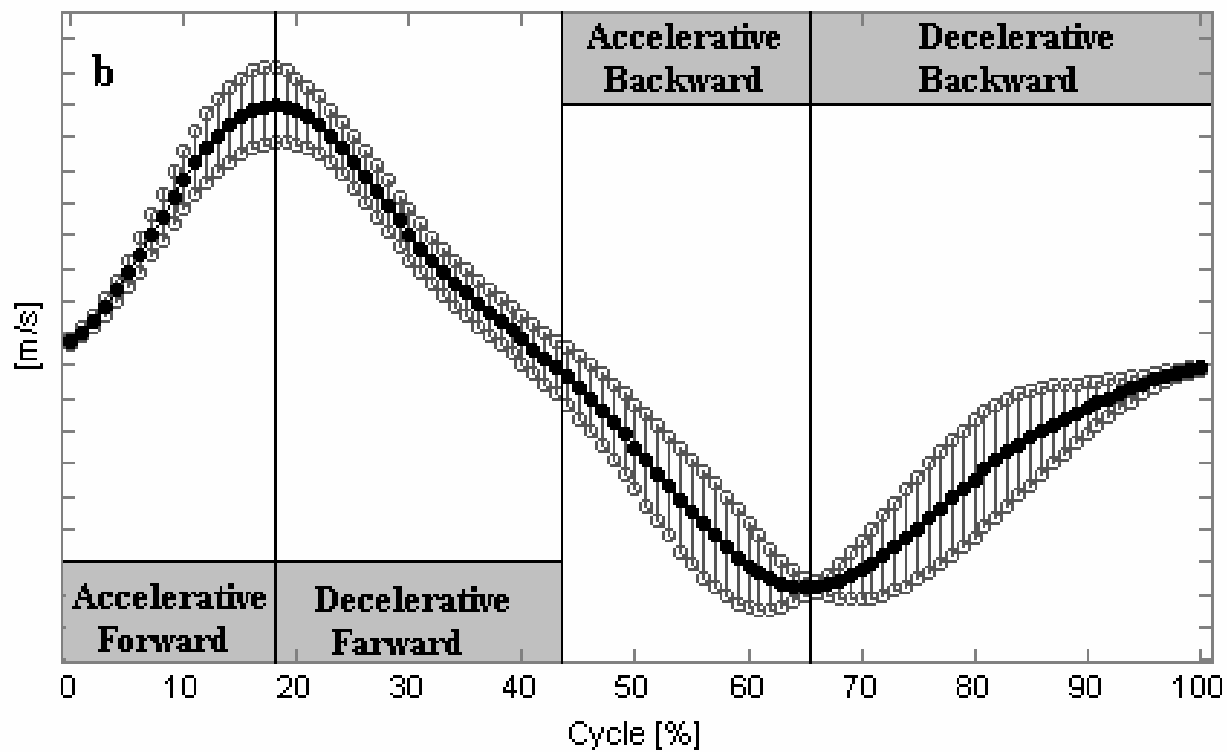
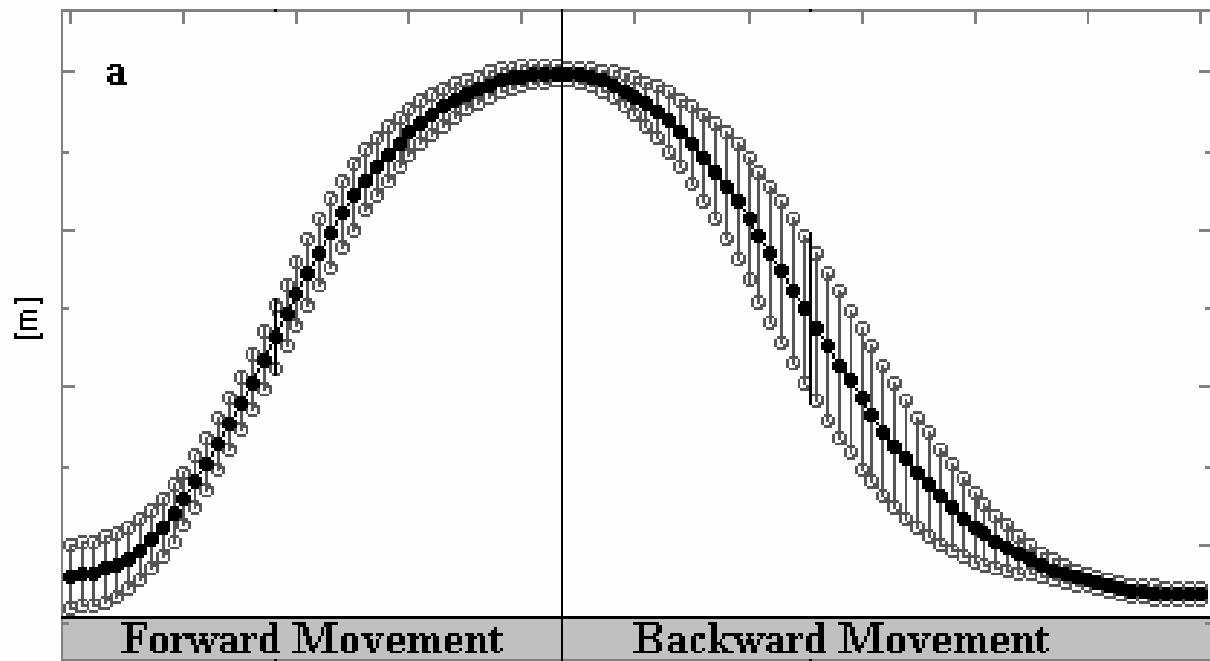
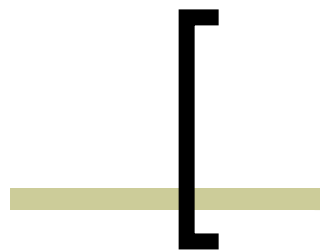




# [ four movement phases ]

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- Forward movement (FM), during which the subject reached for the cylinder, then backward movement (BM), during which the subject transported the cylinder back. Then each movement was furtherly divided into an acceleration and a deceleration phase,

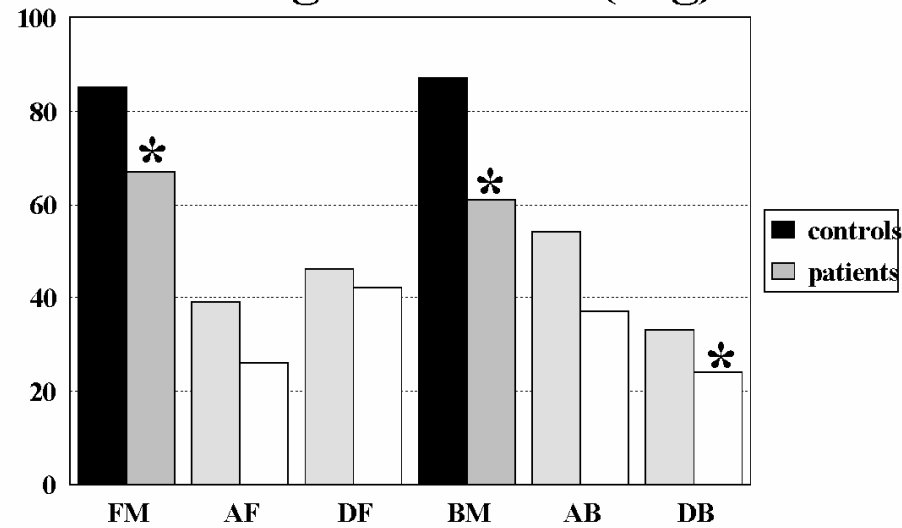


# [ ranges of motion (ROMs) ]

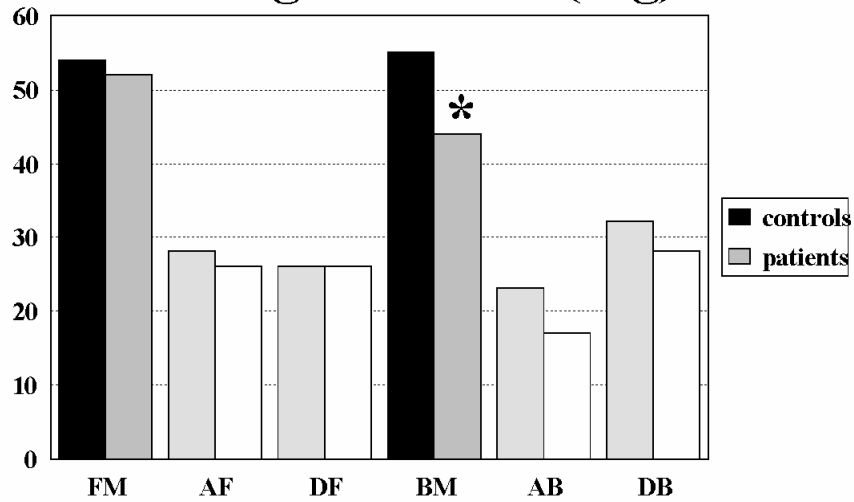
- **elbow** (flexion-extension);
- **shoulder** (anteflexion-retroflexion, horizontal adduction-abduction and abduction-adduction);
- **trunk** (flexion-extension, torsion, lateral flexion).

# [ Results 1: ROMs ]

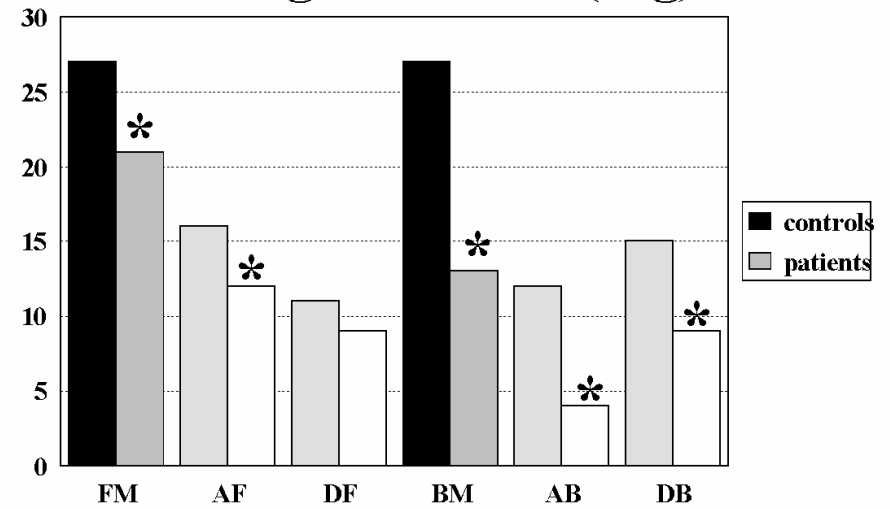
**elbow flexion-extension  
range of motion (deg)**



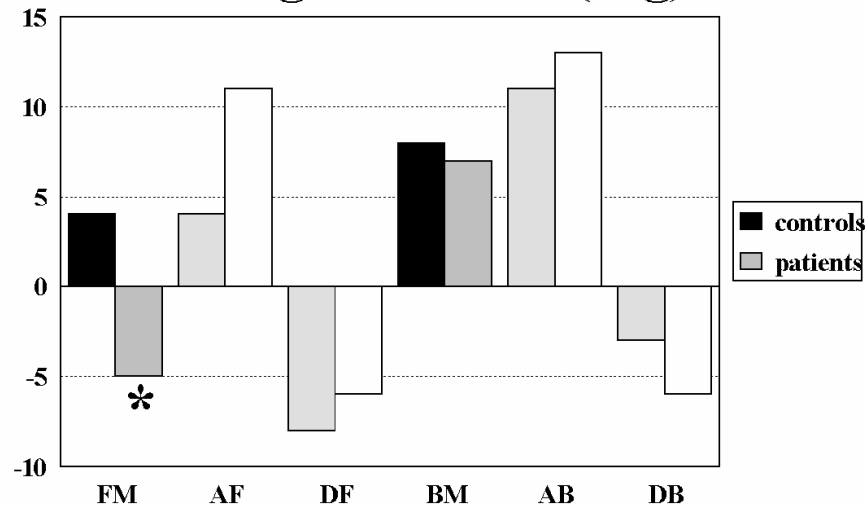
### shoulder anteflexion-retroflexion range of motion (deg)



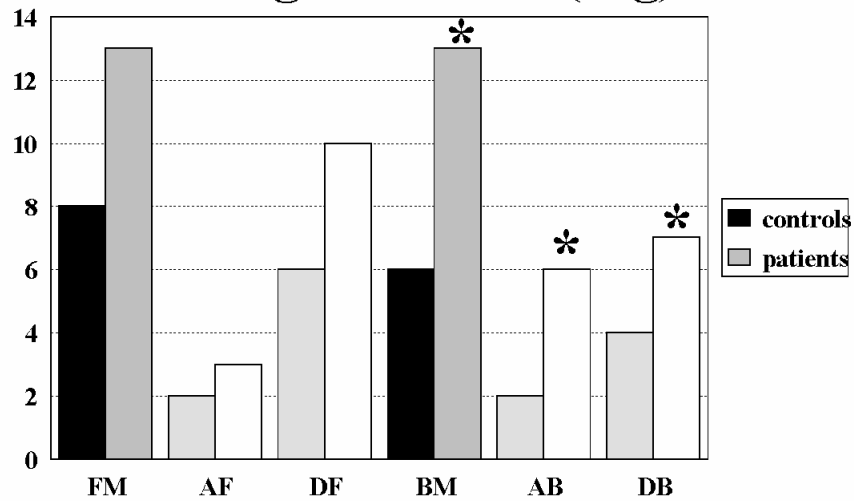
### shoulder horizontal adduction-abduction range of motion (deg)



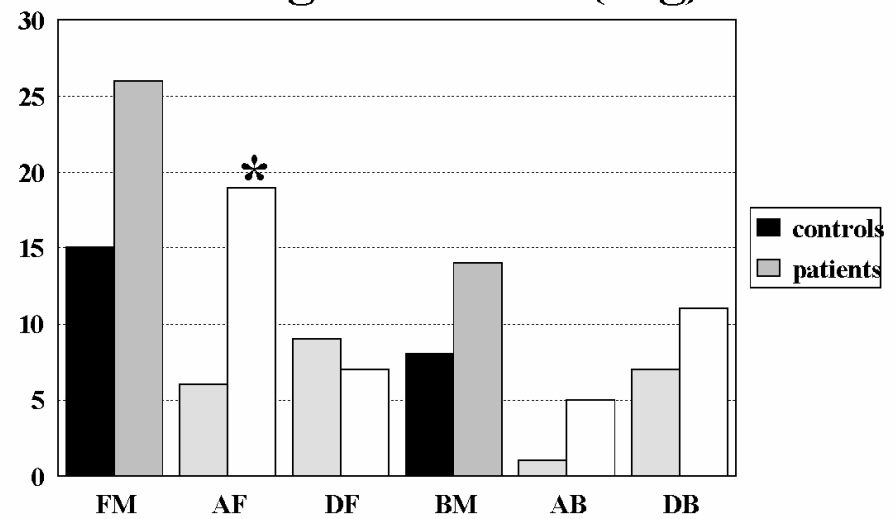
### shoulder adduction-abduction range of motion (deg)



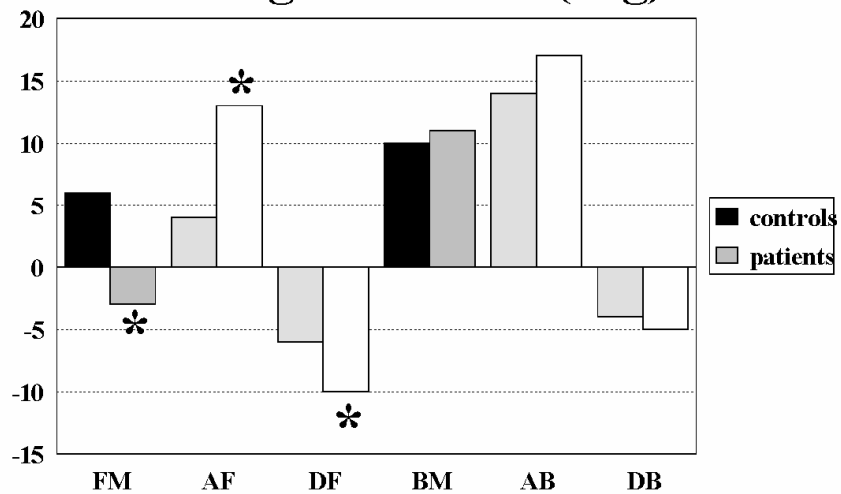
### trunk flexion-extension range of motion (deg)



### trunk torsion range of motion (deg)



### trunk lateral flexion range of motion (deg)



## **[Results 2: continuous relative phase (CRP)]**

- a DST tool allowing a continuous measure of coupling or phase relationships between the actions of two interacting joints or segments;
- a low dimensional parameter compressing four variables in one measure.

# CRP computing

Angular Position and Velocity Normalization

$$\theta_{iN} = \frac{2 * [\theta_i - \min(\theta_i)]}{\max(\theta_i) - \min(\theta_i)} - 1$$

$$\omega_{iN} = \frac{\omega_i}{\max[\max(\omega_i), \max(-\omega_i)]}$$

Joint Phase Angle

$$\varphi = \tan^{-1} \frac{\omega_{iN}}{\theta_{iN}}$$

CRP

$$\phi = |\varphi_{DJ}| - |\varphi_{PJ}|$$

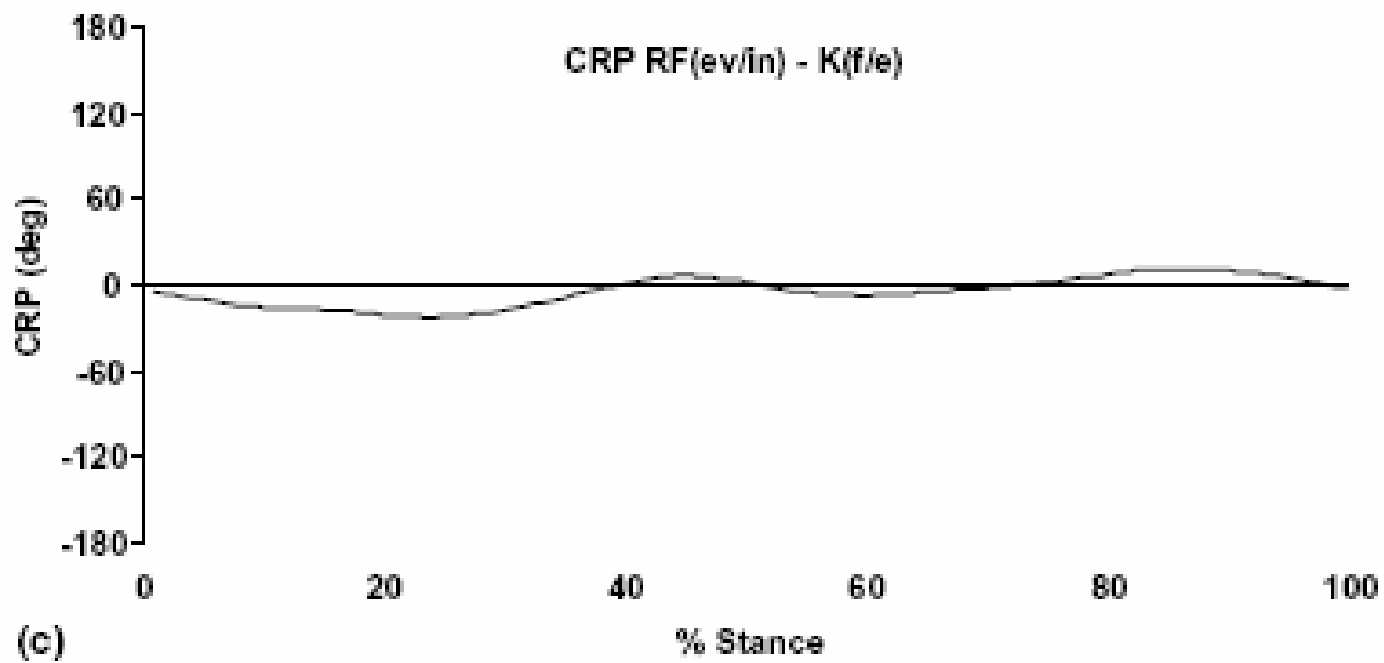
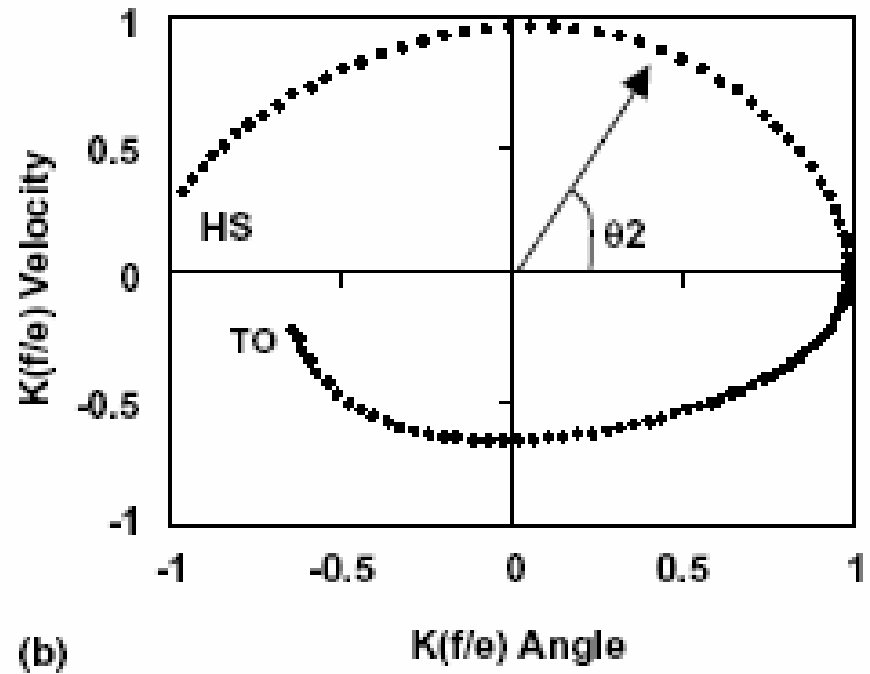
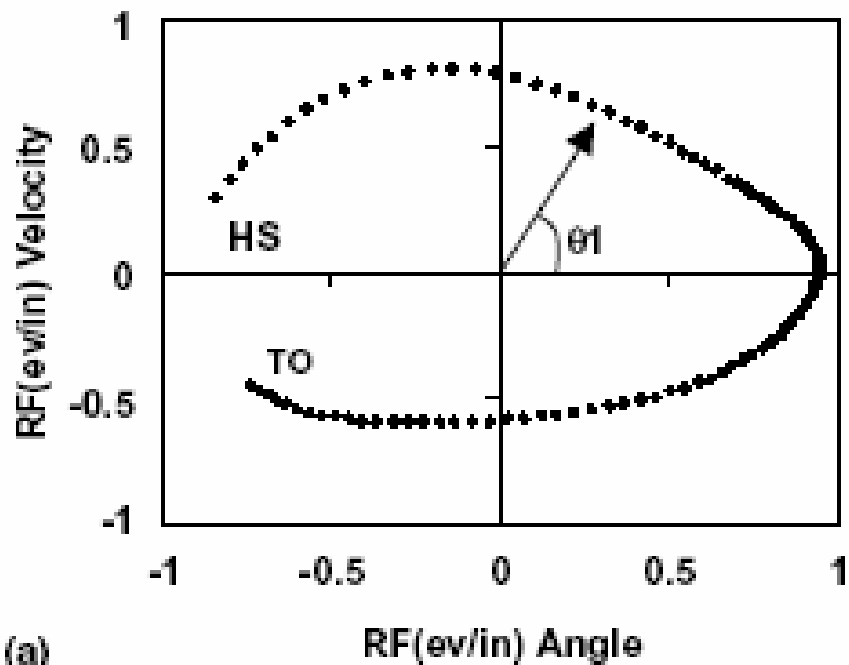
CRP=0° indicate a complete in-phase coupling, CRP=90° or -90° indicate a complete anti-phase coupling

## Statistical Analysis:

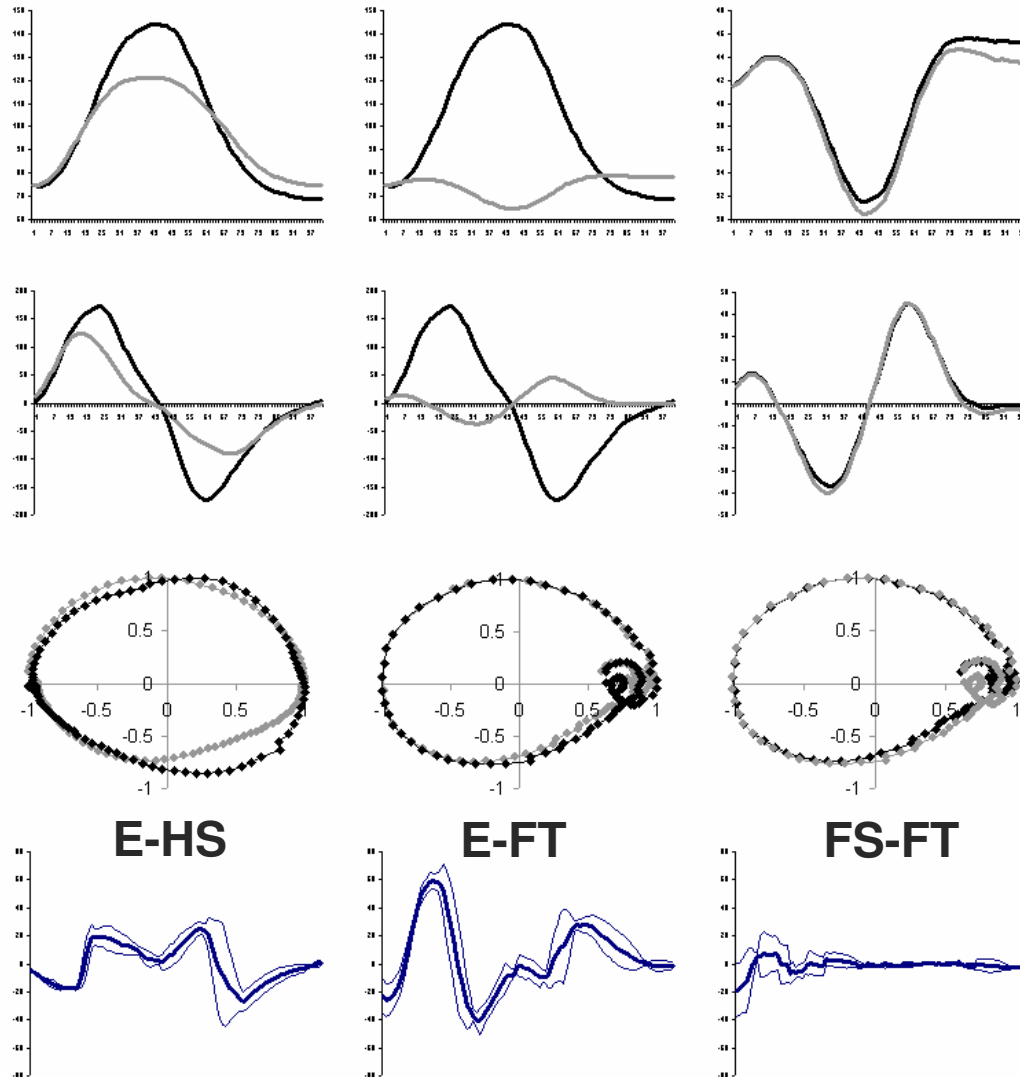
The Coefficient of Multiple Correlation (*Neter 1985, Winer 1971, Kabada 1989, Steinwender 2000*) was used to quantify, within and between subject, the similarity among different continuous relative phase relationships

$$R_{IS} = \sqrt{1 - \frac{\frac{1}{T(N-1)} \sum_{i=1}^N \sum_{t=1}^T (y_{it} - \bar{y}_t)^2}{\frac{1}{TN-1} \sum_{i=1}^N \sum_{t=1}^T (y_{it} - \bar{y})^2}}$$

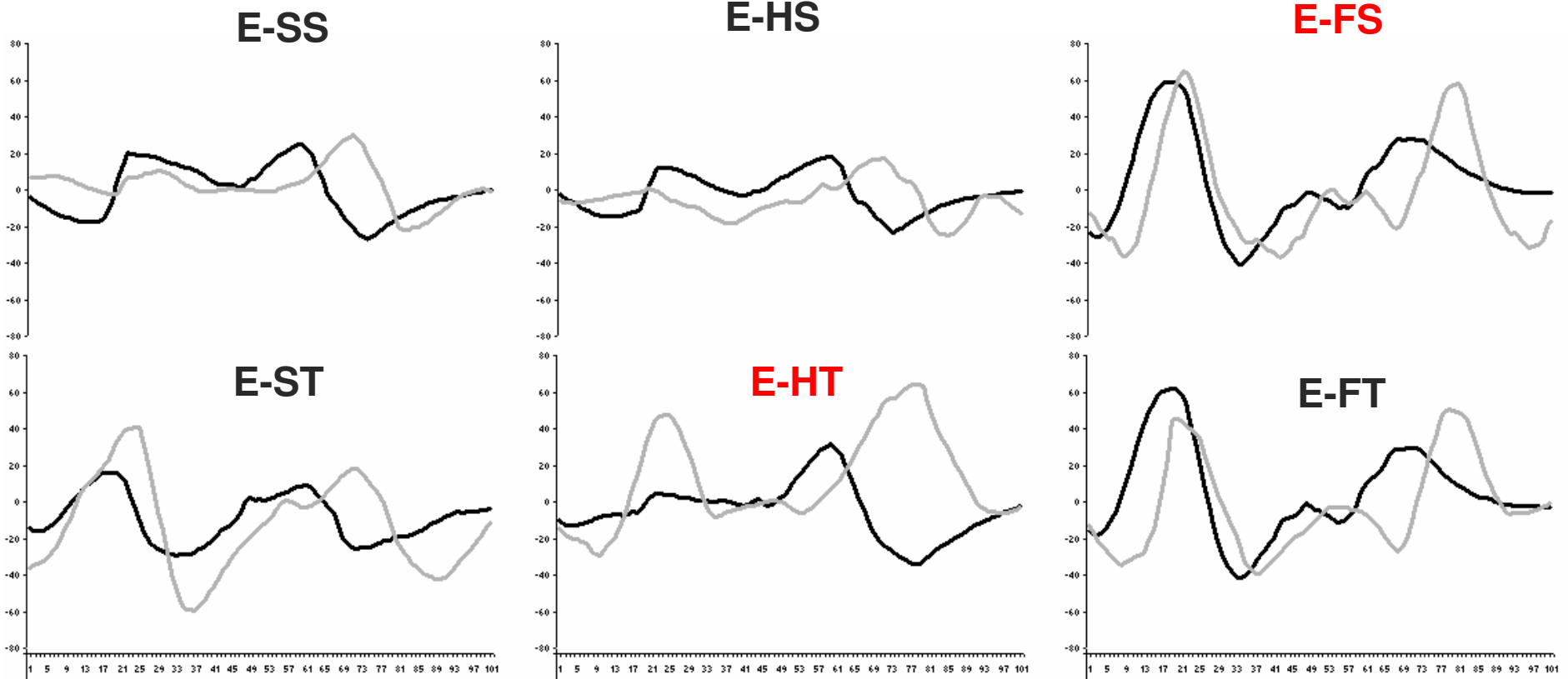
$$R_{BS} = \sqrt{1 - \frac{\frac{1}{ST(N-1)} \sum_{s=1}^S \sum_{i=1}^N \sum_{t=1}^T (y_{sit} - \bar{y}_t)^2}{\frac{1}{STN-1} \sum_{s=1}^S \sum_{i=1}^N \sum_{t=1}^T (y_{sit} - \bar{y})^2}}$$



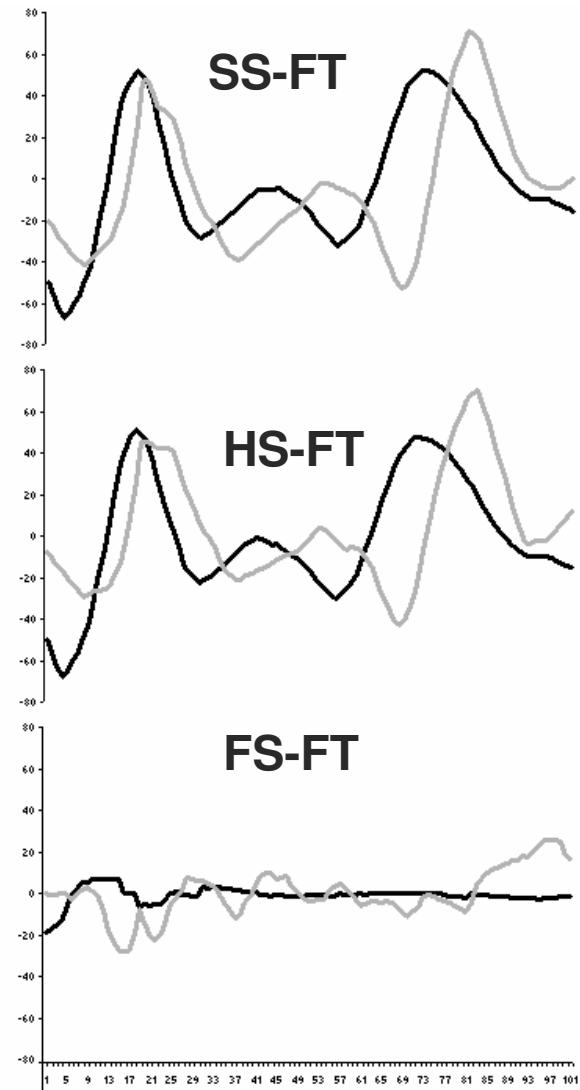
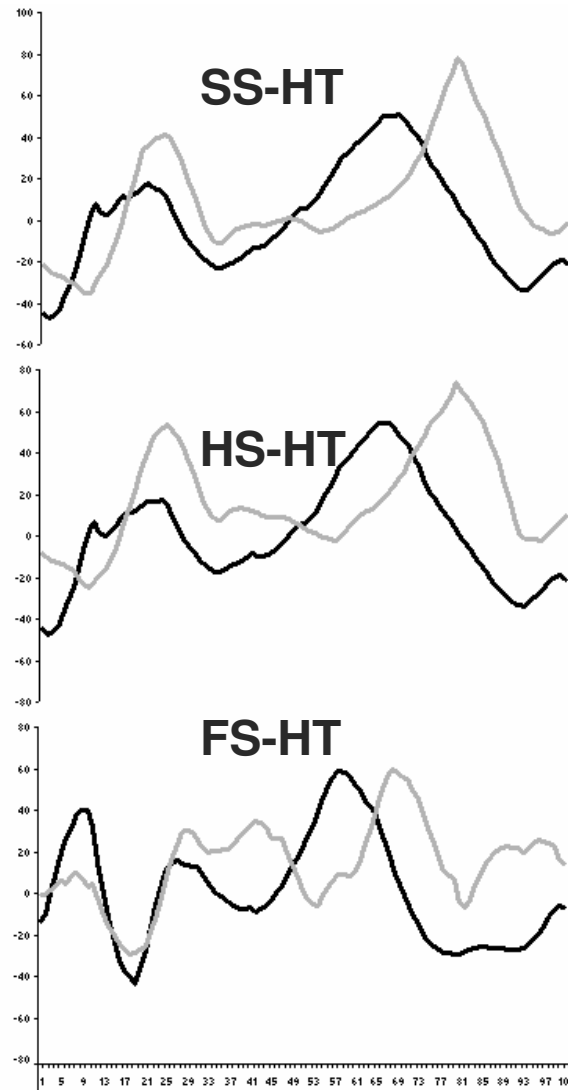
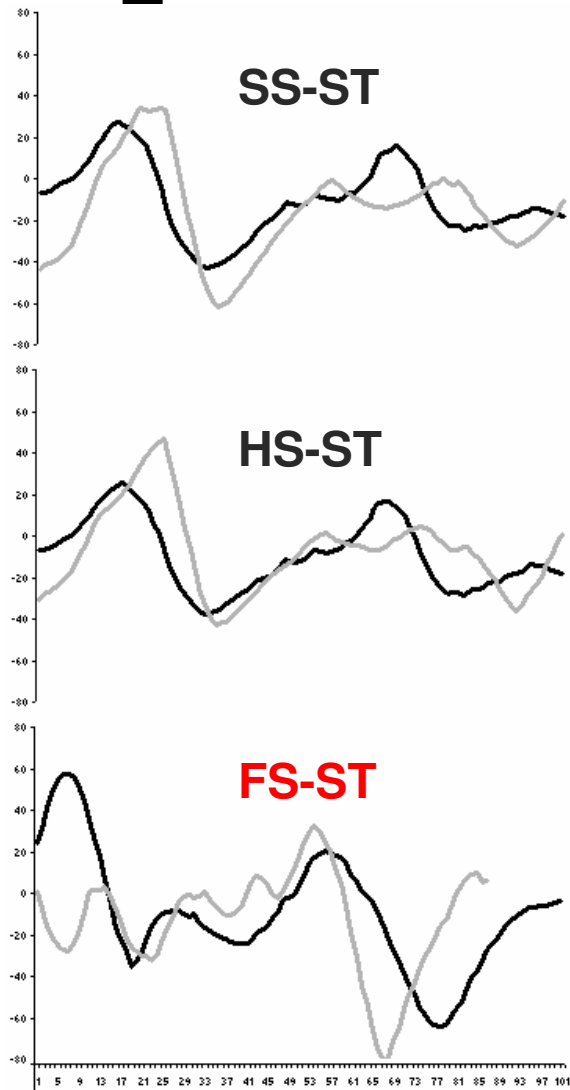
# hierarchical and synergic coupling



# elbow/shoulder elbow/trunk



# [ shoulder/trunk ]



# [ conclusions ]

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- ROMs and CRPs can contribute to fully understand the biomechanics of upper limb in reaching and grasping movements by approaching the issue of joints and trunk coordination;
- patients affected by functional limitations involving their arms need to vary their motor strategy by use of the trunk for motor rather than stabilization purposes.