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Sporting expertise influences the EMG - torque relationship during an isometric contraction

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Introduction:

- Muscular contraction = result of chemical and electrical phenomena whose resultant effect can be quantified as the net joint torque generated by the muscles around the mobilized joints.
- The electrical activity associated with this effort can be recorded at a muscular level by electromyography (EMG).

→ Study of the relationship between EMG and torque.

- EMG = indicator of muscular activity, necessary to integrate in order to develop a physiologically realistic model of the musculoskelettal system.

Introduction:

- Relationship between Torque and EMG very controversial whatever the kind of contraction (dynamic or isometric).
- Isometric Moment – EMG relationship:
  - Hof (1997), Onishi & al (2000) → linear
  - Marras & Granata (1997) → curvilinear
  - Monod & Flandrois (2003) → more complicated : 2 stages (Fig.1)

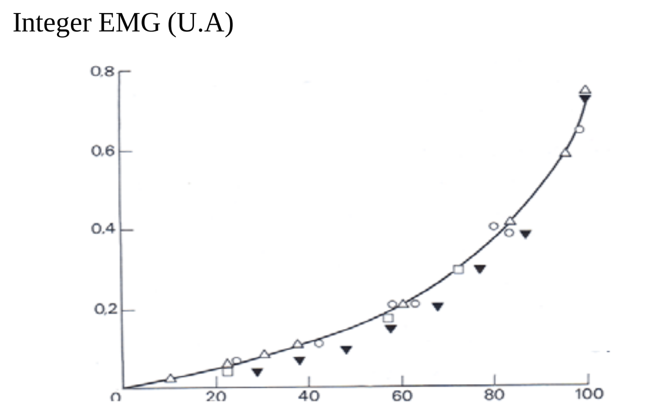


Fig.1: Non-linearity of the EMG-Force relationship (Monod & Flandrois, 2003)

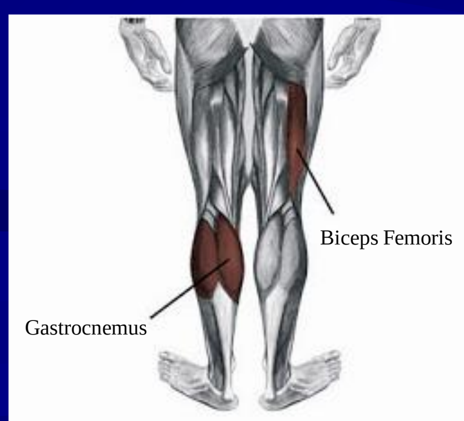
Introduction:

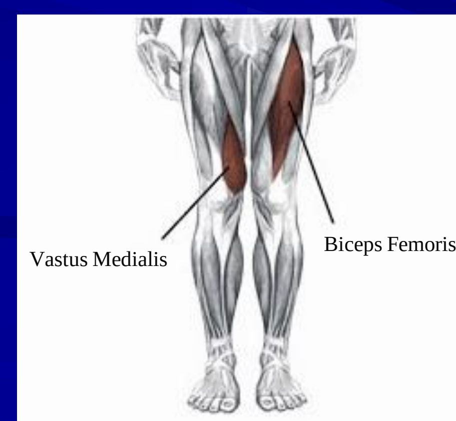
- This relationship between Torque and EMG has never been studied taking into account the influence of the expertise.
- Hypothesis:

  We investigate the effect of expertise in force production exercises on the nature of the EMG-torque relationship under the hypotheses that motor unit synchronisation and myotypology in experts enhance the performance of the muscular contraction.

Methods:

- Participants
  - 5 male experts in force production exercice (age: 24,6 3,25 years ; height: 1,79 0,08 m ; mass: 75,75 10,75 kg)
  - 5 male novices (age: 21,8 2,28 years; height: 1,78 5,04 m; mass: 75,4 6,15 kg)
- Apparatus
  - Electromyography (Bagnoli-8 EMG system, Delsys, 1000Hz)
    - Flexor muscles: Gastrocnemus, Biceps Femoris
    - Extensor muscles: Vastus Medialis, Rectus Femoris





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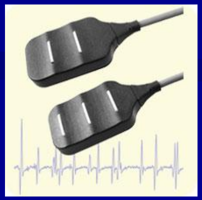
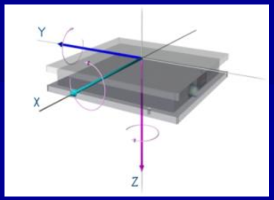
- Apparatus
  - Electromyography (Bagnoli-8 EMG system, Delsys, 1000Hz)
    - Flexor muscles: Gastrocnemus, Biceps Femoris
    - Extensor muscles: Vastus Medialis, Rectus Femoris
  - Kinematic (Vicon MX system , 200Hz)
  - Ground reaction force (AMTI, 1000Hz)





Methods:

- Protocol

  - Sat down, right foot firmly attached to the force plate, trunk vertical, thighs horizontal and lower legs flexed at 90 (Fig.2).

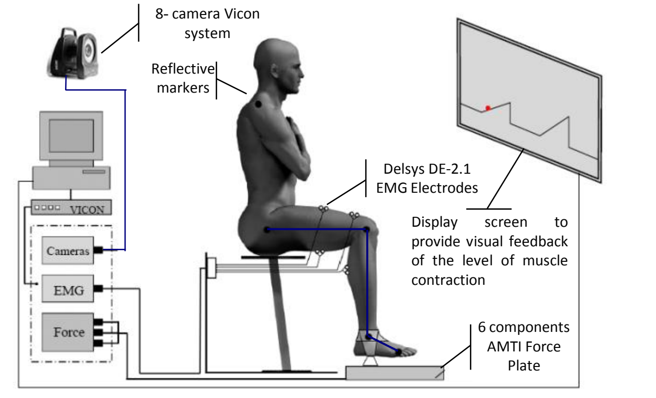


Fig.2: experimental protocol

- The experimental protocol comprised 2 stages

  - 3 successive maximal isometric contractions in flexion then in extension

  - 6 muscle contraction trials each consisting of a 10 s knee flexor isometric contraction (0-100% MVC), followed by a 10 s knee extensor isometric contraction (0-100% MVC)

Methods:

- Data processing and modelling
  - *Kinetics:* calculation of the net moment acting at the knee
    - ground reaction, joint angular positions and body segments' parameters
    - standard link-segment equations in static conditions (Winter, 2004).
  - *EMG processing:*
    - band-pass filter 10 Hz to 400 Hz (Hermens et al., 1999),
    - full-wave rectified,
    - Envelops (Shiavi and al., 1998).
    - Normalisation
  - *Establishment of the EMG-moment relationship*
- Regressions and statistics
  - EMG-moment relationship was fitted by linear or curvilinear (quadratic) regression
  - A two-factor (expertise and contraction type) ANOVA with repeated measures on factor contraction type were conducted on %CoAct.
  - A significance level of 0.05 was used for all statistical tests

Results:

- ## MVC Moment

Significant effect of force production expertise on maximum net knee joint moment produced during isometric MVC (Fig.1)

- Higher values for experts than for novices in flexion (-802   222 N·m vs. -359   301 N·m; t8 = 2.65, $p < 0.05$)

- Higher values for experts than for novices in extension (530   135 N·m vs. 340   123 N·m; t8 = 2.34, $p < 0.05$).

- Higher values in flexion than in extension only for expert (802   222 N·m vs 530   135 N·m ; t8 = 2.34, $p < 0.05$)

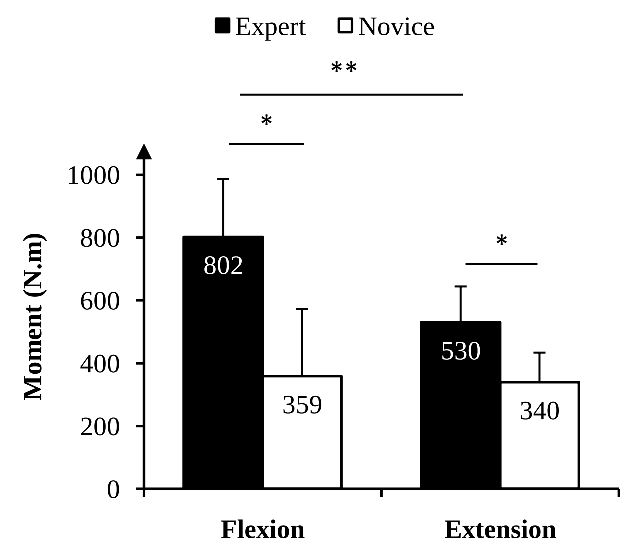


Fig.2: Maximum torque performed at the knee in flexion and extension during the MVC. * Significant sporting expertise effect ($p < 0.05$). ** Significant contraction effect ($p < 0.05$).

Results:

- Isometric EMG – Moment Relationship: Experts

  - *Linear* (fig 3 & 4) whatever the *contraction type*, the *muscle* and its *role* during the contraction.

  - Low value of antagonist muscles activation.

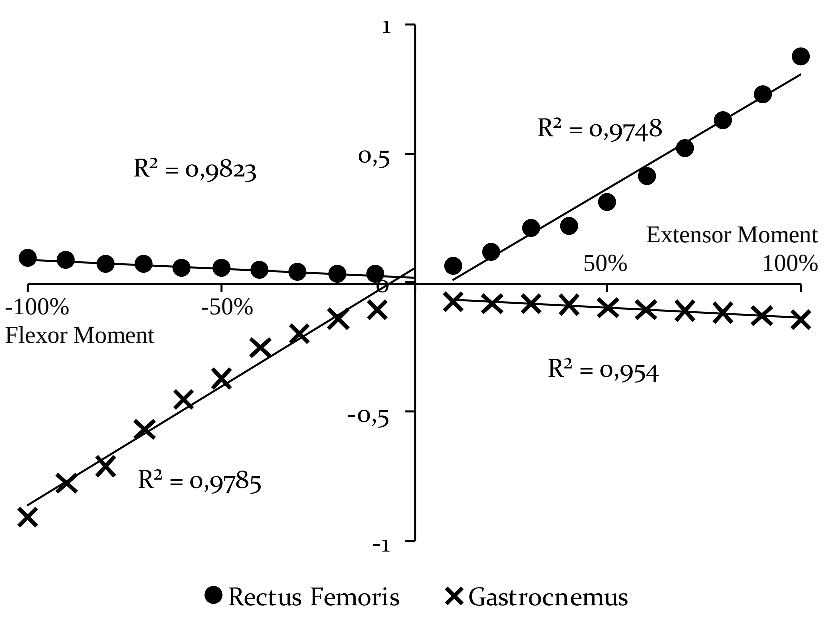


Fig 3: isometric EMG – moment relationship for Experts in Biceps Femoris and Gastornemus muscles

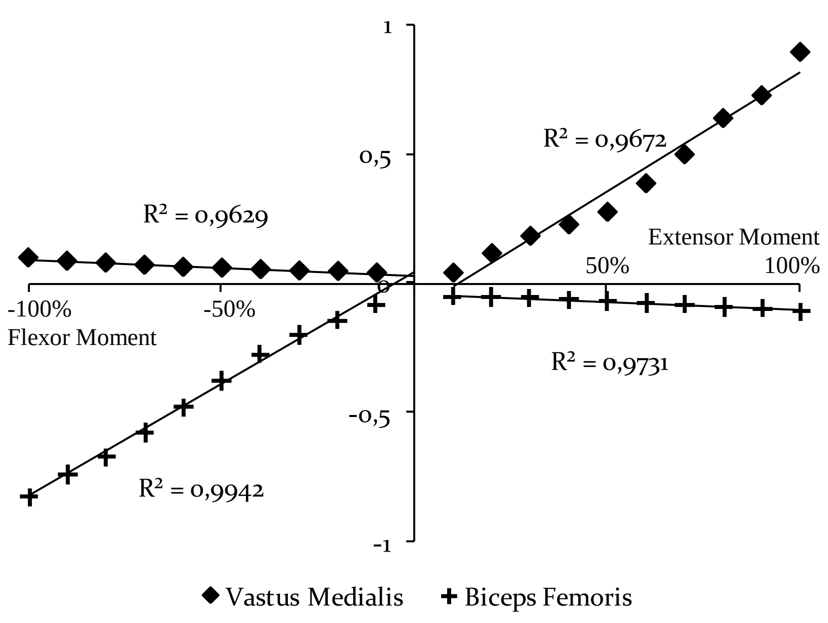


Fig 4: isometric EMG – moment relationship for Experts in Biceps Femoris and Gastornemus muscles

Results:

- Isometric EMG – Moment Relationship: Novices

  - *Curvilinear* (quadratic) (fig 5 & 6) whatever the *contraction type*, the *muscle* and its *role* during the contraction.

  - High values of antagonist muscle activation.

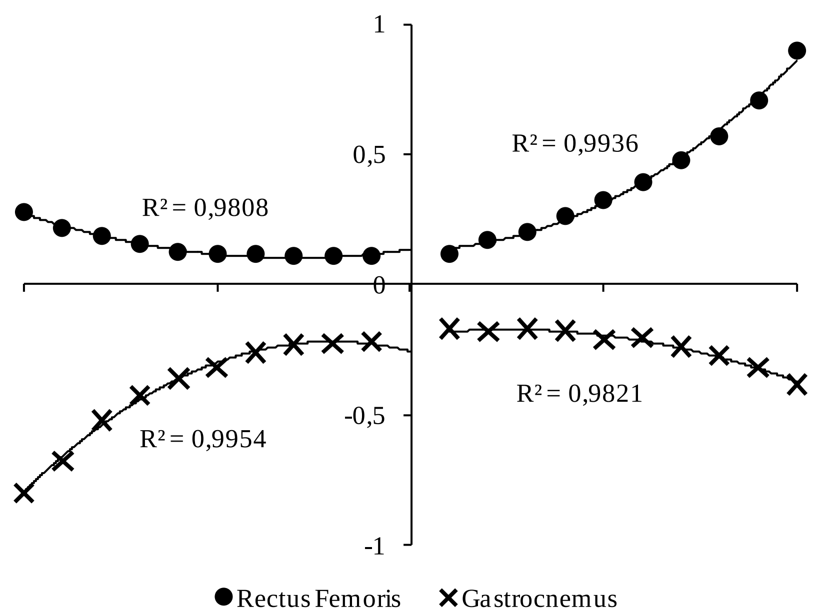


Fig 5: isometric EMG – moment relationship for Novices in Rectus Femoris and Gastornemus muscles

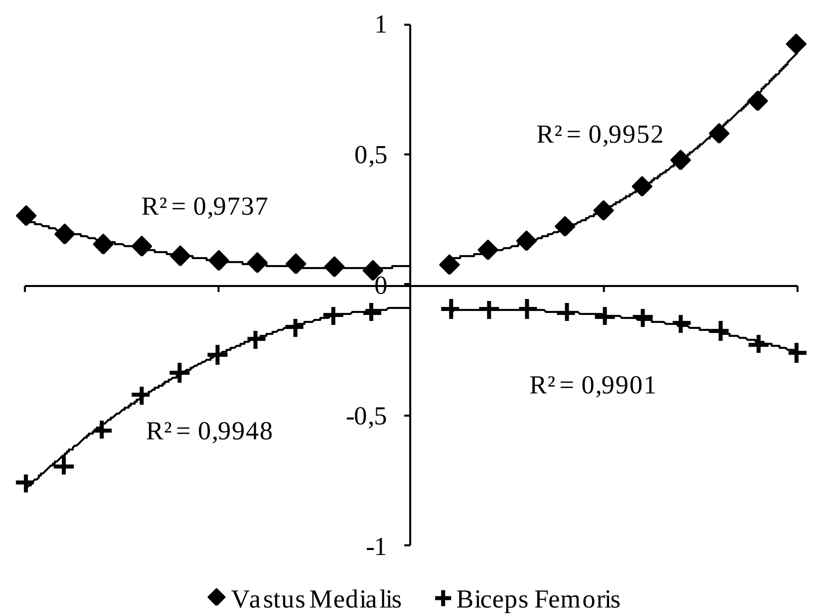


Fig 6: isometric EMG – moment relationship for Novices in Vastus Medialis and Biceps Femoris muscles

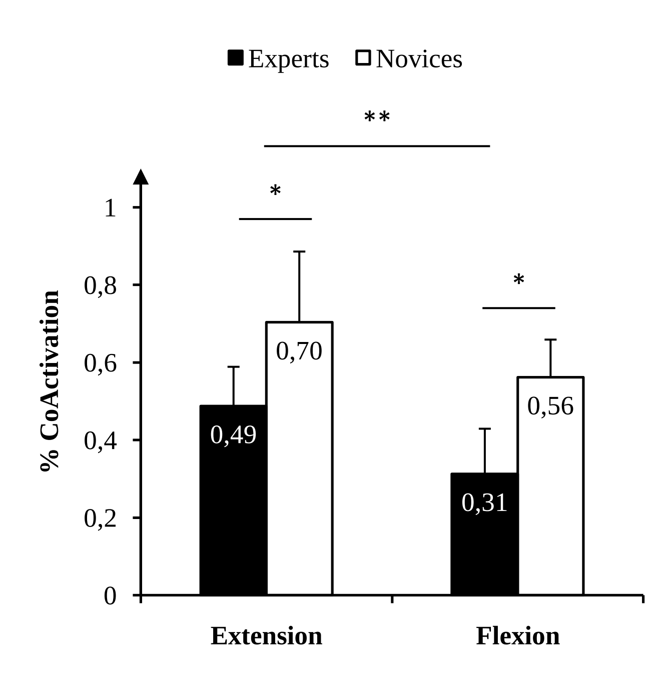
Results:

- % Co-activation

significant effect of expertise in force production exercises on the level of co-activation of knee agonist/antagonist muscle pairs (Fig.1)

- %CoAct values higher for novices than for experts ($F1,8 = 1.88$, $p < 0.05$; mean %CoAct: 63   3% vs. 40   3%, respectively).

- %CoAct significantly higher in extension than in flexion ($F1,8 = 5.48$, $p < 0.05$; mean %CoAct: 59   4% vs. 44   3%, respectively).



Discussion:

- Isometric EMG-Moment relationship & % Co-activation

  - ***Experts:***
    - Strictly *linear* (Hof (1997) , Onishi & al (2000))
    - *Antagonist muscles control* would be *energetically advantageous.*

  - ***Novices:***
    - *Curvilinear* (quadratic), 2 phases:
      - 0 – 50% MVC, the MVC values increase quicker than the EMG values.
      - 50 – 100% MVC, the EMG values increase quicker than the MVC values.
    - *Antagonist muscles control* would be *energetically less advantageous.*

Discussion:

- Limits:
  - Number of subjects
  - Only for an isometric contraction
- Perspective:
  - Dynamic contraction (most difficult → dependant on many factors)
- Interest:
  - Control of robot manipulator using EMG

    → Sagawak K., Kimura O. (Control of robot manipulator using EMG generated from face, 2005)

    → Artemiadis P.K. & Kyriakopoulos K.J. (Teleoperation of a robot manipulator using EMG signals and a position tracker, 2005)

  - Robotic system for the rehabilitation using EMG signals in order to assure mechanical help

    → Tsujiuchi N. (Myoelectric upper-limb prostheses, use of a linear regression model between force and EMG)

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