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Influence of Expertise on the EMG-Torque Relationship during Isometric Contraction in Man

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Introduction:

Muscular contraction is the 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). The study of **the relationship between EMG and torque** is an important element in understanding the mechanisms underlying, and the factors affecting, muscle force production. Moreover, the nature of the EMG-torque relationship remains controversial whatever the kind of contraction: e.g. linear [1], quadratic or curvilinear [2] for isometric contractions.

The present work investigates the **influence of expertise in force production on the EMG-moment relationship** under the hypotheses that motor unit synchronisation and myotypology specific to experts enhance the performance of the muscular contraction.

Methods:

Participants & Apparatus

- **10 male subjects** (5 experts, 5 novices)
- **Kinematic** (Vicon, 200 Hz)
- **Kinetic** (AMTI, 1000 Hz)
- **Electromyography** (Delsys, 1000Hz):
  - → Knee Extensors: Rectus Femoris (**RF**) & Vastus Medialis (**VM**)
  - → Knee Flexors: Biceps Femoris (**BF**) & Gastrocnemus (**Ga**)

Protocol

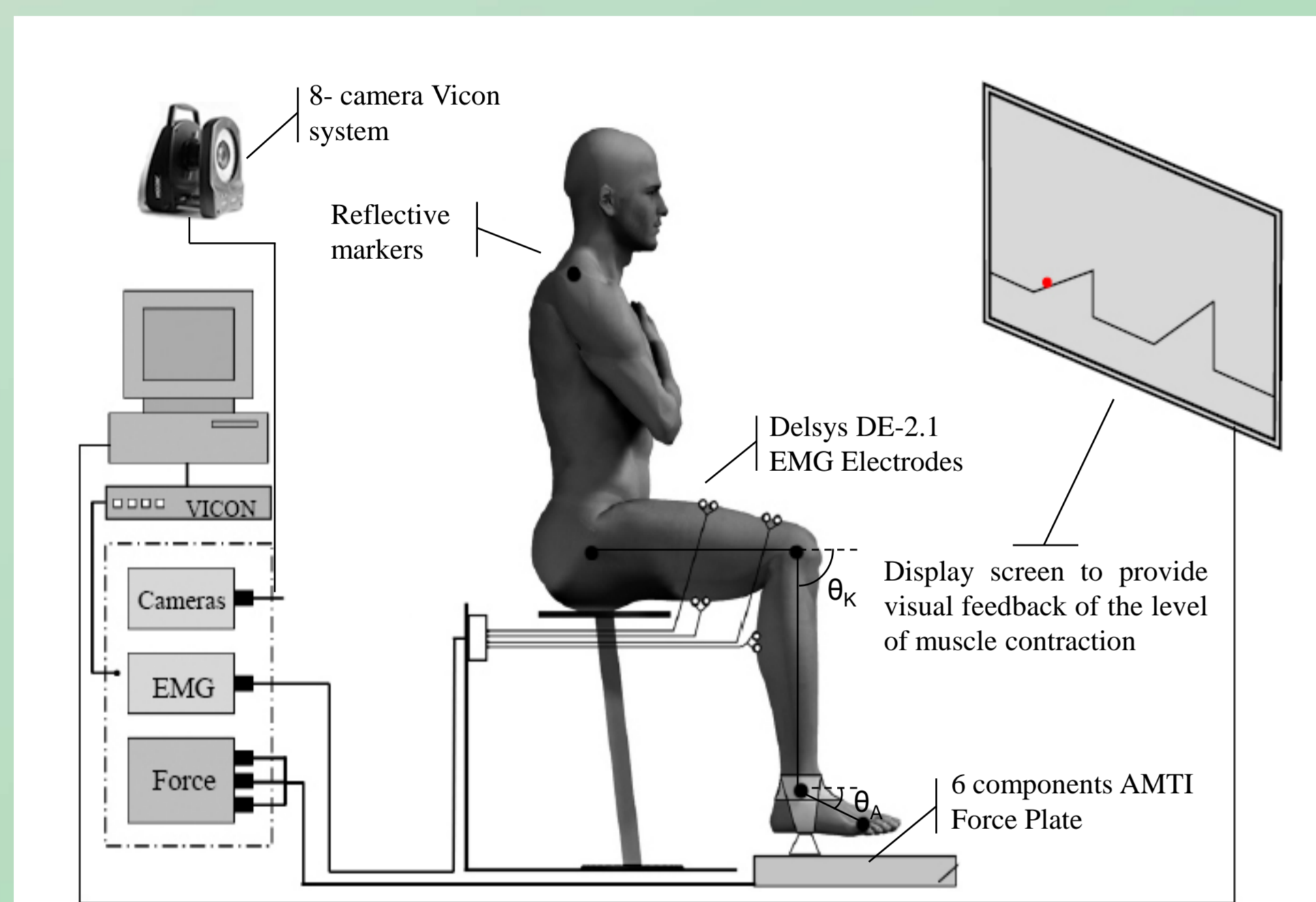- sat down, right foot fixed to the force plate (Fig. 1)

Fig. 1: Experimental protocol.

- **Protocol:**
  - — Evaluation of the maximal isometric force (MVC) in flexion then in extension
  - — MVC test (Median frequency computation)
  - — 6 trials – 10s isometric contraction (0 - 100% MVC) in flexion then in extension
  - — 3 min rest period between 2 trials

Data processing

- **Kinetic:** net knee moment calculated from:
  - — ground reaction
  - — joint angular positions
  - — body segments' parameters
- **EMG:** normalization of the EMG envelops
- Indirect **myotypology estimation** [3]

Results:

MVC & Myotypology

- **Muscle Fibre type I proportion** higher for novices: $47.64 \pm 4.40\%$ vs. $38.33 \pm 5.69\%$
- **MVC moment values:** higher for experts (Fig. 2):
  - → **Flexion:** Experts: 802 ± 222 N·m vs. Novices: 359 ± 301 N·m ($t_8 = 2.65$, $p < 0.05$)
  - → **Extension:** Experts: 530 ± 135 N·m vs. Novices: 340 ± 123 N·m ($t_8 = 2.34$, $p < 0.05$)
- No significant relationship between the MVC extension moment and VM muscle fibre type I proportion

CoAct

- **Agonist-antagonist co-activation:** %CoAct values higher for novices than for experts (mean %CoAct: $63 \pm 3\%$ vs. $40 \pm 3\%$; $F_{1,8} = 1.88$, $p < 0.05$) (Fig. 3)
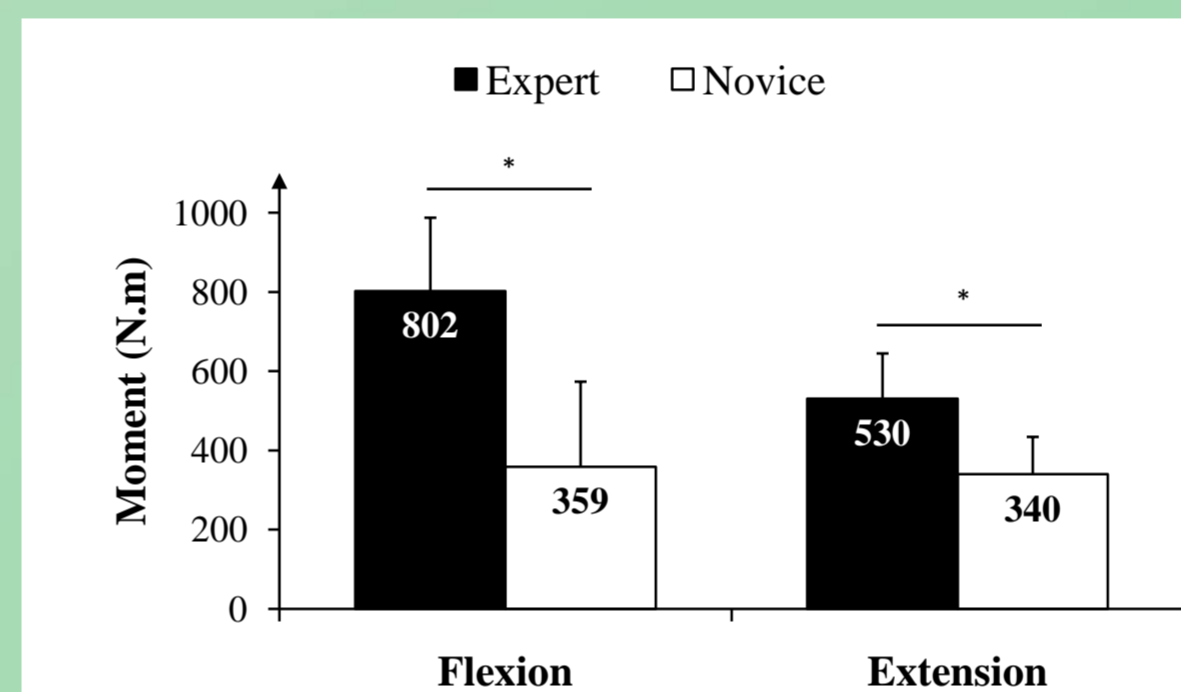

Fig. 2: Maximum torque performed at the knee in flexion and extension during the MVC test in expert (■) and novice (□) males.
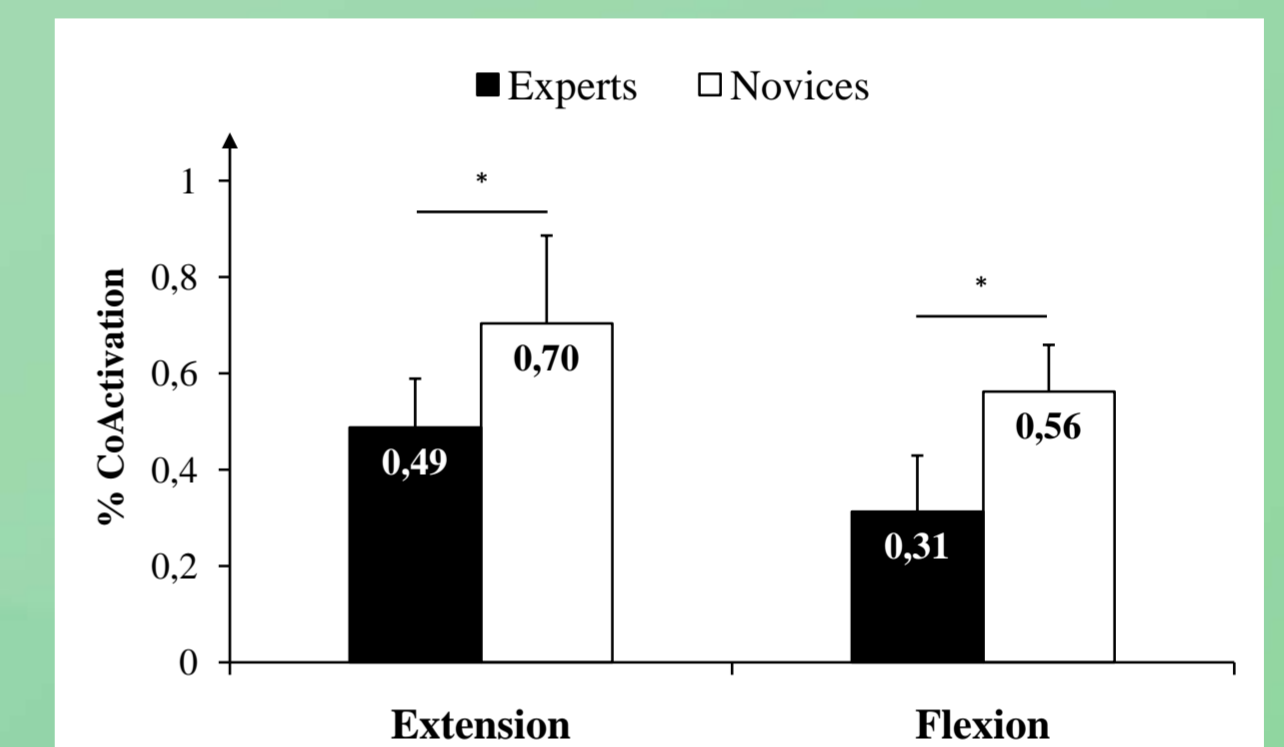

Fig. 3: % Co-Activation in expert and in novice males during extension and flexion.

EMG – Moment relationship

- **Experts: linear** whatever the muscle group and its role, and whatever the contraction type (Fig. 4a)
- **Novices: curvilinear** (quadratic) whatever the muscle group and its role, and whatever the contraction type (Fig. 4b)
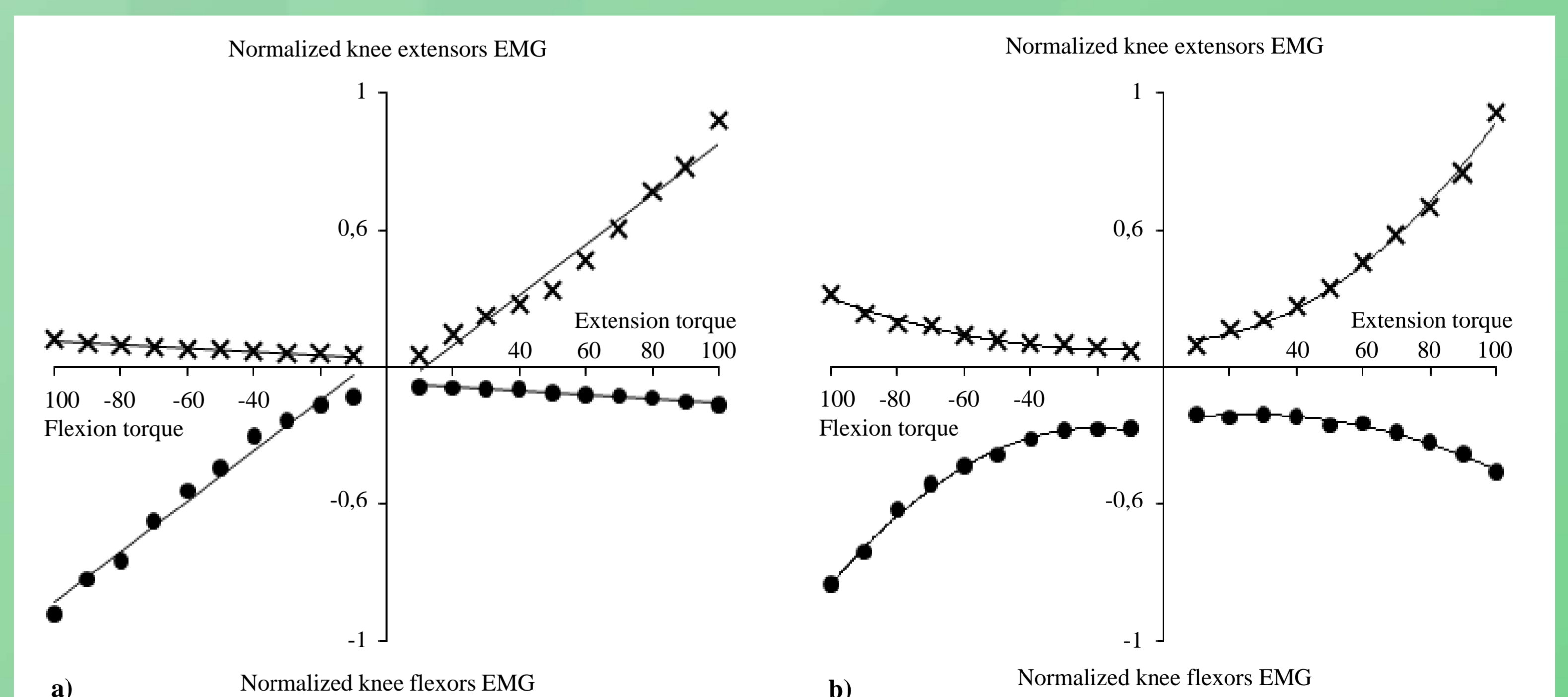

Fig.4: Normalized EMG-torque relationship a) in experts and b) in novices. VM (**x**) and Ga (●).

Discussion:

In general, our results on the relationship between EMG and the net joint moment obviously indicate that the higher the net knee joint moment, the higher the EMG activity, whatever the muscle and its role, the contraction type and the level of expertise. However, our results show that **the relationship between EMG and torque is not strictly linear** and prove that **expertise in force production is a decisive factor of the nature of the EMG-torque relationship**. Moreover, our findings support the idea that the observed differences between experts and novices are mainly determined by changes in motor unit recruitment and synchronization following force production training.

In addition, our results suggest that training in force production involves energetic optimization by the enhancement of the agonist/antagonist muscles co-contraction, thus contributing to improved muscle contraction efficiency and seems to induce a favourable control of the muscular contraction with *optimal* level of antagonist muscle activation in experts.

The present work may find applications for the development of EMG-based models for muscle force estimation, or for the design of robotic systems for rehabilitation using EMG signals.

References:

[1] Onishi, H., Yagi, R., Akasaka, K., Momose, K., Ihashi, K.; Handa, Y., 2000. Relationship between EMG signal and force in human vastus lateralis muscle using multiple bipolar wire electrodes. Journal of Electromyography and Kinesiology **10**, 59-67.

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[3] Wretling M.L., Gerdle B. and Henriksson-Larsen K. EMG: a non-invasive method for determination of fibre type proportion. Acta Physiologica scandinavica, **131**, 627-628.