Effects of plyometric training on the mechanical and geometrical properties of the plantar flexor muscle-tendon complex

Alexandre Fouré, Antoine Nordez, Christophe Cornu

EFFECTS OF PLYOMETRIC TRAINING ON THE MECHANICAL AND GEOMETRICAL PROPERTIES OF THE PLANTAR FLEXOR MUSCLE-TENDON COMPLEX

UNIVERSITÉ DE NANTES

Motricité, Interactions, Performance
Equipe de recherche EA 4334

Alexandre Fouré, Antoine Nordez, Christophe Cornu

University of Nantes, France. Laboratoire "Motricité, Interactions, Performance" - EA 4334
✉ UFR STAPS, 25 bis Bd Guy Mollet – BP 72206, 44 322 Nantes cedex 3, France, email : alexandre.foure@univ-nantes.fr

Introduction

Stiffness of tendinous and muscular structures is involved in **tension transmission to the skeleton** and in **storage-recoil of elastic energy process** during movements as stretch shortening cycle [1].

Plyometric training (PT) has already been shown to increase vertical jump performances which could be attributed to changes in the mechanical properties of muscle-tendon complex (MTC) rather than muscle activation strategies [2]. Previous studies hypothesized **specific adaptations of the MTC structures** [3] with a decrease in active part of the series elastic component (SEC_1) stiffness (i.e. better storage of elastic energy) and an increase in passive part of the series elastic component (SEC_2) stiffness (i.e. better recoil of elastic energy stored and better muscular tension transmission).

The aim of this study was to determine **the effects of PT on the stiffness of the structures involved in the ankle joint plantar flexion** using a method previously used in animal models [4] in order to **assess possible specific local adaptations of their elastic properties.**

Methods

Subjects: 19 males divided to trained (TG, *n*=9) and control groups (CG, *n*=10).

Material: - Mechanical signals as ankle joint angle (θ), angular velocity (ω) and torque (T) (Isokinetic dynamometer Biodex Pro 3®).
- Surface electromyography activities (SEMG) of the *triceps surae* muscles (Delsys®).
- Ultrasonographic images (Philips® HD3).

Protocol : - Jump tests (Squat Jump [SJ], Counter Movement Jump [CMJ] and Reactive jumps [RJ]).

- Short range stiffness experiment + Alpha method: quick dorsiflexion (ω=250°/s) during constant submaximal isometric contractions (Fig 1).

- Achilles tendon stiffness measurement (S_{AT}): determination of the Achilles tendon displacement using ultrasonography during isometric increased plantarflexion.

- Achilles tendon cross sectional area (CSAt) measurement using ultrasonography at rest.

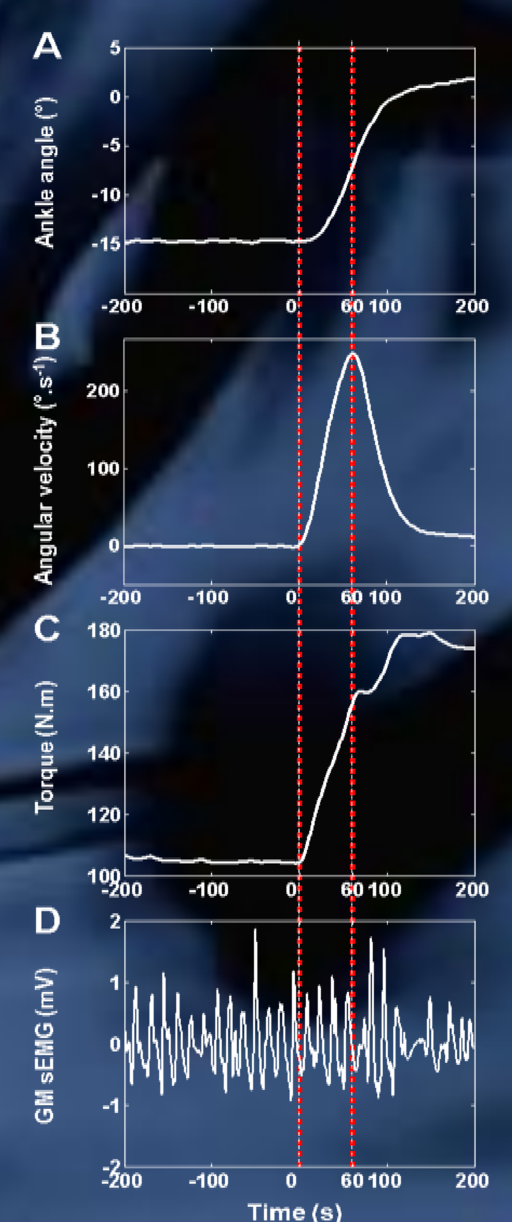

Figure 1 : Typical raw data obtained during a trial of the short range stiffness experiment: the first 60 ms of the stretch were used

Data Processing: From the global measurement of joint stiffness (S=ΔT/Δθ) and using the alpha method (Eq. 1, Fig. 2), determination of :
- Stiffness index of the SEC_1 (SI_{SEC1}) .
- Stiffness of the SEC_2 (S_{SEC2}) assumed as constant on the torque range (30 to 90% MVC) [5].

$$\text{Alpha} = \frac{T}{S} = \frac{1}{SI_{SEC1}} + \frac{1}{S_{SEC2}} \times T \qquad (1)$$

Results

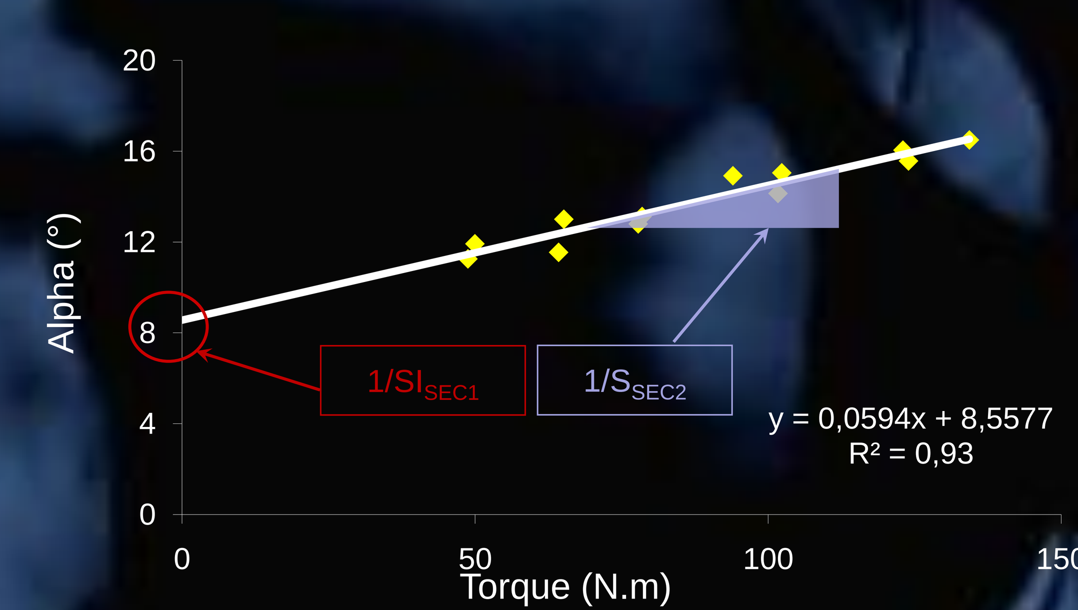

Figure 2: Typical example of Alpha-Torque relationship obtained for one subject plotted with the stiffness index of active structures (SI_{SEC1}) defined as the inverse of the Y-axis intercept and the stiffness of passive structures (S_{SEC2}) as the inverse of the slope of the relationship.

- ↗ **jump performances** for TG (changes between +7.3% and +26.5% according to the jump form).

- ↗ **joint stiffness** at 80% MVC (+4.2%) and S_{SEC2} (+16.6%) for TG (Fig. 3).

- ↘ SI_{SEC1} (-19.6%) for TG (Fig. 3).

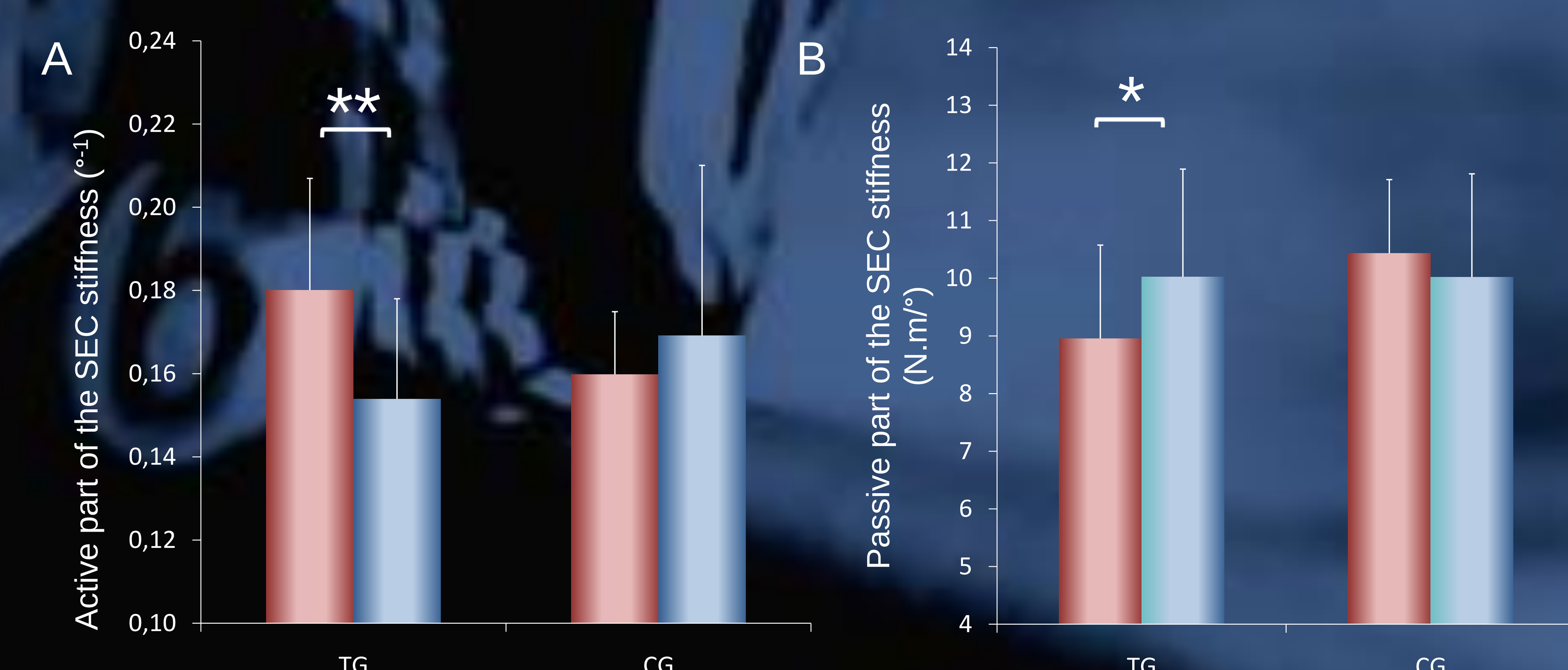

Figure 3: Stiffness of the active (A) and passive (B) part of the series elastic component (SEC) before ( ) and after ( ) 14 weeks of plyometric training period for trained (TG) and control (CG) groups (: p<0.05; **:p<0.01).*

- No significant change in CSAt (p>0.05) for TG.

- Good correlation between changes in the S_{AT} and the S_{SEC2} after 14 weeks of plyometric training (p<0.01).

- For all the parameters, no significant change was found for the CG (p>0.05).

Discussion – Perspectives

The major results showed **an increase in the ankle joint stiffness** with specific changes of the SEC passive and active parts stiffness. **These opposite adaptations between active and passive structures of the MTC** could be responsible for **a better efficiency of the energy storage-recoil process** by the MTC (i.e. as described in introduction) leading in part to an **increase in jump performances.**

Furthermore, the increase in the passive part of the SEC stiffness (mainly representing tendon structures) found in the present study is correlated to the change in Achilles tendon stiffness determined using ultrasonography during isometric contraction. No change was found in Achilles tendon CSA. Then, **change in Achilles tendon stiffness could be due to changes in the qualitative properties of the tendinous tissues** rather than changes in geometrical parameters of the Achilles tendon structures.

References

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