



Effects of plyometric training on the stiffness and dissipative properties of the Achilles tendon

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Introduction

Plyometric training (PT) is known to improve vertical jump performances [e.g. 1]. During a plyometric exercise, the mechanical properties of the Achilles tendon, such as **stiffness and dissipative properties, underlie the elastic energy storage-recoil process and the transmission of muscular tension** [2]. Astonishingly, PT effects on Achilles tendon dissipative properties were little studied.

These mechanical properties may also play a role in debilitating injuries, including Achilles tendon rupture or tendinopathy [3]. A comprehensive **assessment of the geometric properties** of the Achilles tendon (i.e., cross sectional area) **is needed to discuss the nature of the potential physiological mechanisms involved** in the changes in mechanical properties after plyometric training.

The aim of the present study was to determine **effects of 14 weeks of PT on the stiffness, dissipative properties and geometric characteristics of the Achilles tendon**.

Methods

Subjects:

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

Data acquisition:

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

Protocol :

- Jump tests (Squat Jump, Counter Movement Jump and Reactive jumps).
- Achilles tendon stiffness (S_{AT}) determination and tendon cross sectional area (CSA_T) measurement.

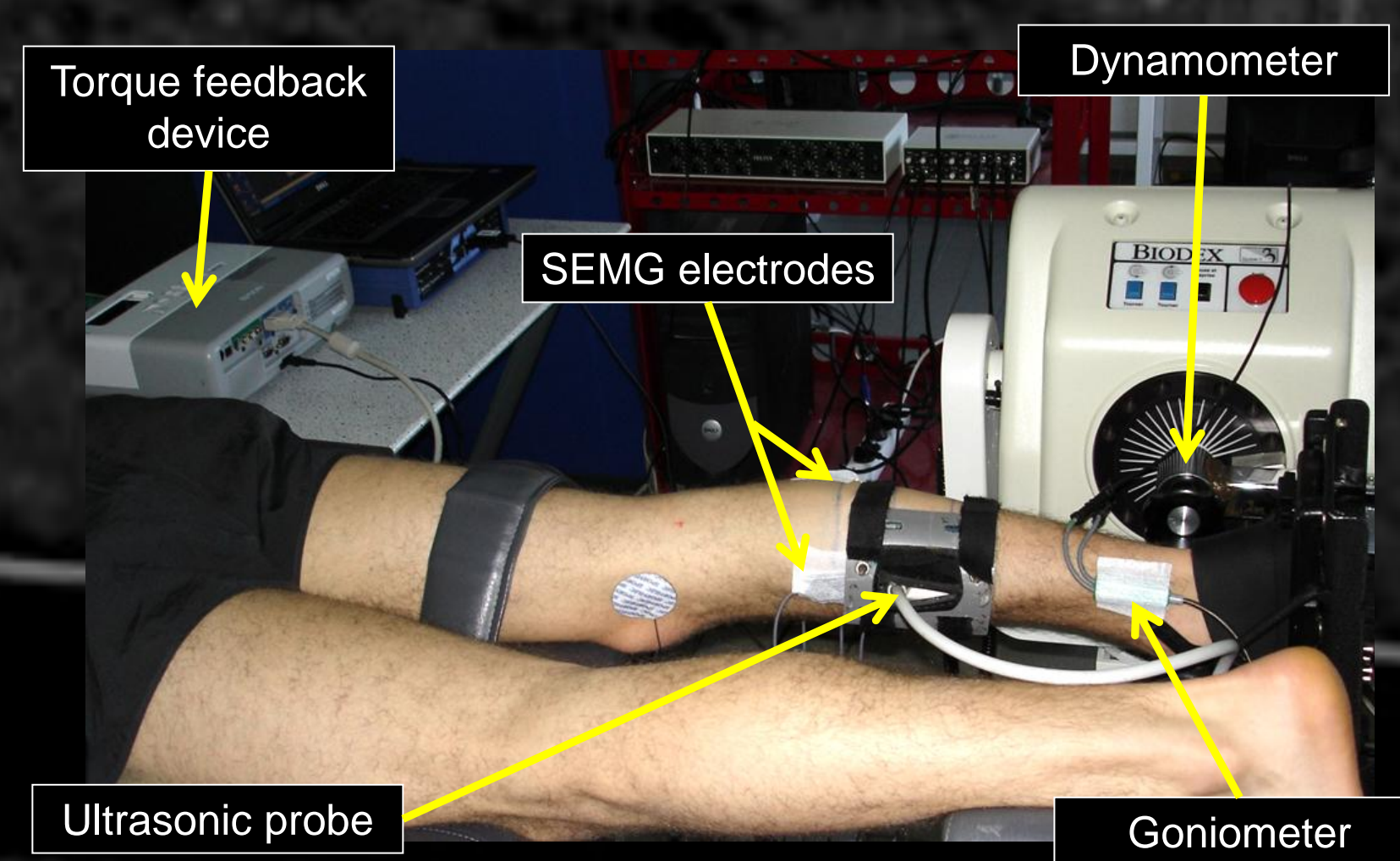


Figure 1: Position of the subject during the isometric plantarflexion from rest to 90% of maximal force and unload to rest

- Subjects lay prone with their legs fully extended (Figure 1). Tendon elongation (ΔL) of the medial *gastrocnemius* determined during isometric plantarflexion using ultrasonography [4].

- Cross-sectional area of Achilles tendon determined using ultrasonography (Figure 2).

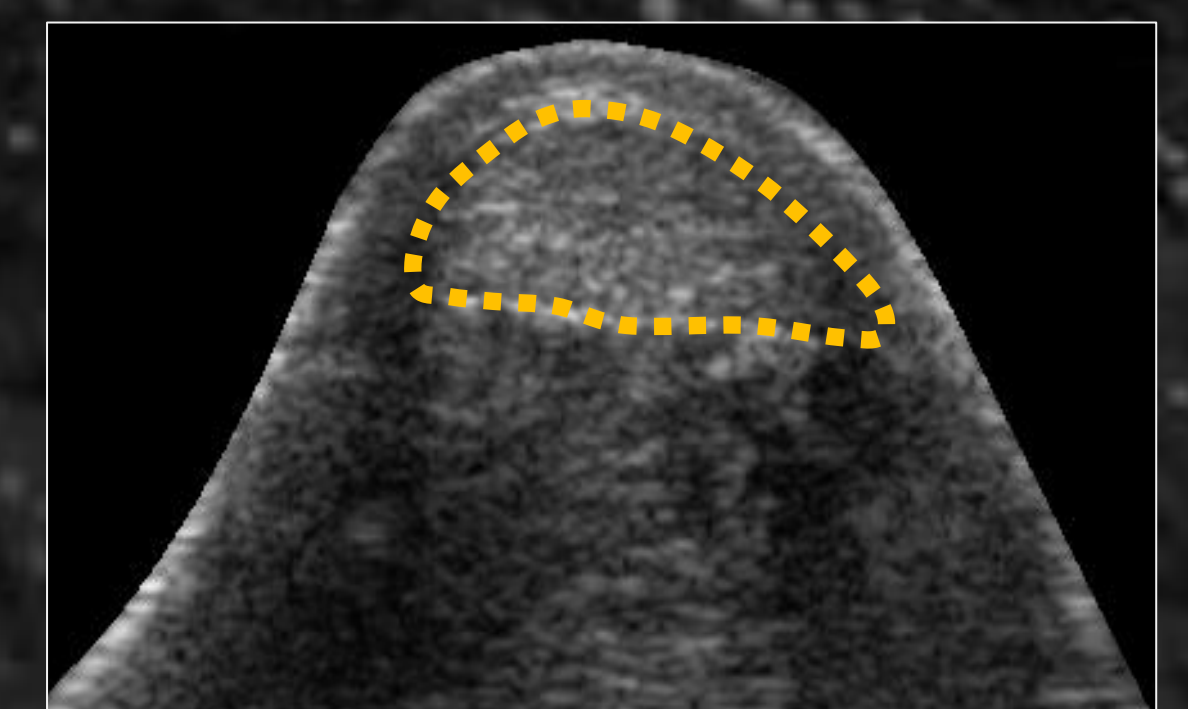


Figure 2: Ultrasonographic scan of the Achilles tendon at rest in the transverse plane at the level of the medial malleolus

Data Processing:

- S_{AT} = slope of the force-elongation (force higher than 50% of maximal force) [5].
- Areas under ascending and descending phases of the curve were used to calculate a dissipation coefficient (DC) [6].
- Two-ways ANOVAs were performed. Critical level of significance was set at $P < 0.05$.

Results

Significant increase in jump performances for the TG : changes between +7.3% and +26.5% according to the jump modality.

Increases of 24.1% and 21.0% in S_{AT} (Figure 3) **and normalized stiffness** (i.e., S_{AT}/CSA) respectively for the TG ($P < 0.05$).

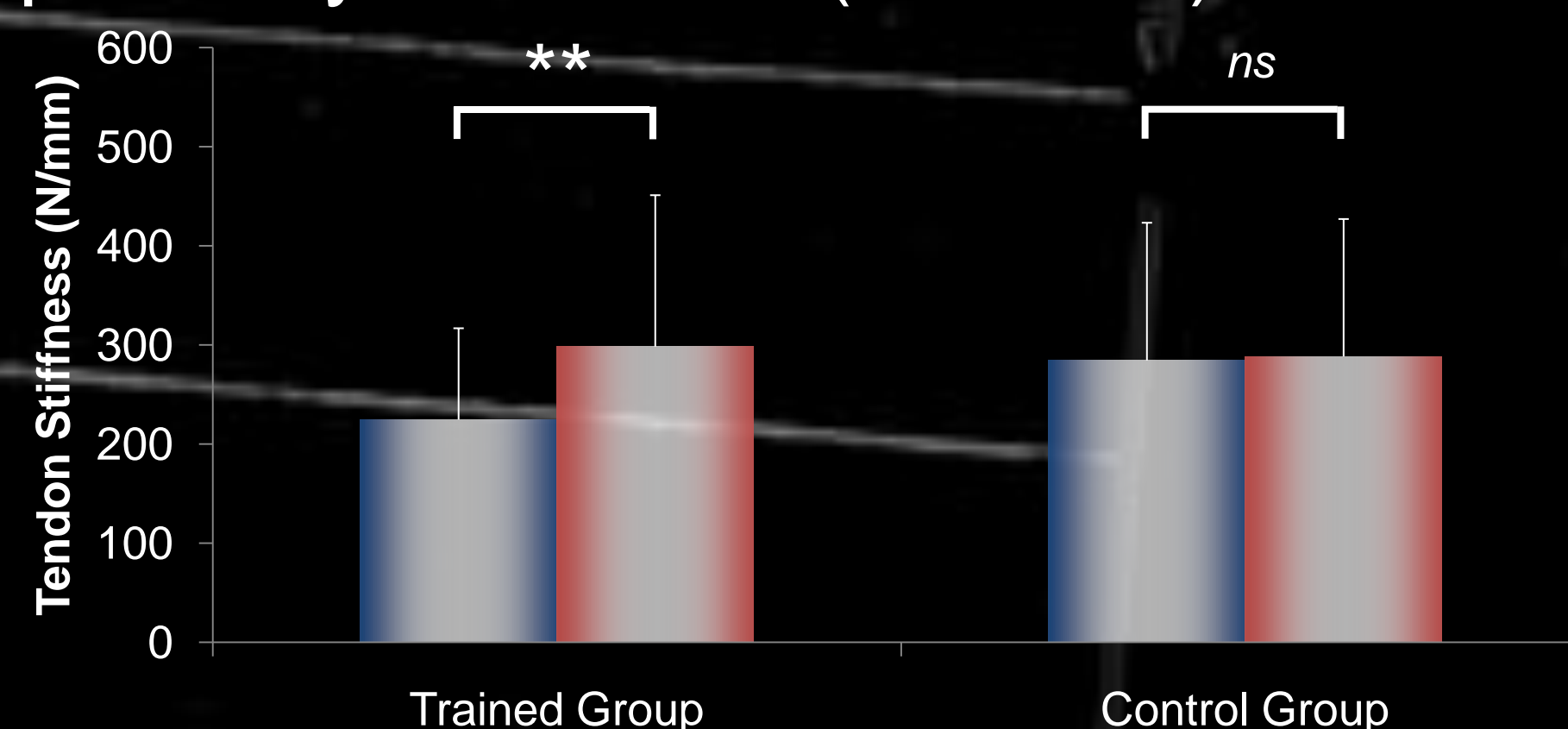


Figure 3: Average of the tendon stiffness (mean \pm SD) between pretest (blue) and posttest (red) for both trained (TG) and control (CG) groups.

** : $P < 0.05$; ns: non-significant.

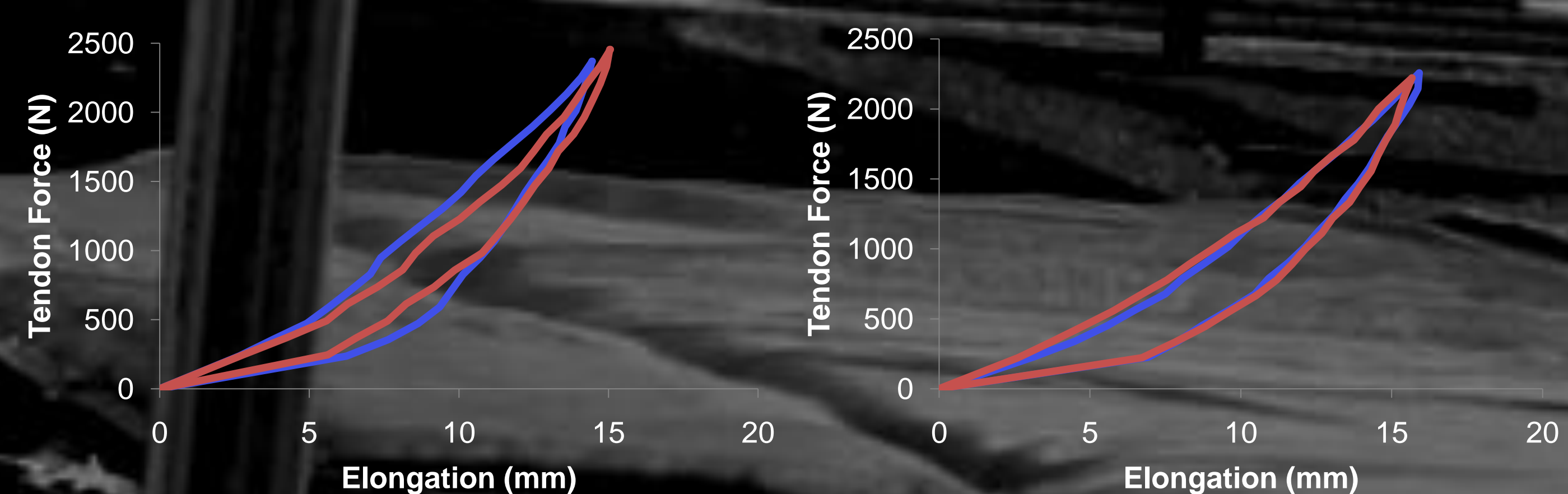


Figure 4: Mean relationship between the tendon force (F_t) and the Achilles tendon elongation (ΔL) in the trained group (A) and the control group (B) in pretest (blue) and posttest (red). Standard deviation bars were removed for clarity.

** : $P < 0.05$; ns: non-significant.

Decrease of 35.0% in DC for the TG ($P < 0.05$), without any changes in Achilles tendon CSA_T ($P > 0.05$).

Discussion

PT enhances the muscular tension transmission through an **increase in stiffness** and a **reduction in energy dissipated** by the tendon. These changes in mechanical properties would **improve muscle tension transmission and the storage-recoil of elastic energy**.

The lack of changes in CSA_T indicates that **changes in mechanical properties** would mainly **result from a qualitative change** in tendinous tissues (e.g., changes in collagen fiber type).

Thus, PT induced **changes in mechanical properties** of Achilles tendon, which **partially explain the performance improvements**, but **may increase the risk of muscle or tendon injuries**.

References

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