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Effects of repeated Achilles tendon vibration on triceps surae stiffness and reflex excitability

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ABSTRACT

Clinical studies frequently report an increase in stiffness and a loss of range of motion at joints placed in disuse or immobilization. This is notably the case for subjects maintained in bed for a long period, whilst their joints are not affected. Recently we documented on healthy subjects the benefit in terms of force and activation capacities of the triceps surae offered by vibrations applied to the Achilles tendon. Knowing that stiffness changes may contribute to force changes, the aim of the present study was to investigate the effects of tendon vibration on the triceps surae stiffness of healthy subjects. The vibration program consisted in 14 days of 1 h daily Achilles tendon vibration applied at rest. Nineteen healthy students were involved in this study. Before and at the end of the vibration program, musculo-tendinous stiffness in active conditions was determined by use of a quick-release test. Passive stiffness was also analyzed by a flexibility test: passive torque–angle relationships were established from maximal plantar-flexion to maximal dorsiflexion. Passive stiffness indexes at 10°, 15° and 20° dorsiflexion were defined as the slope of the relationships at the corresponding angle. Tendinous reflex, influenced by stiffness values, was also investigated as well as the *H* reflex to obtain an index of the central reflex excitability. After the program, musculo-tendinous stiffness was significantly decreased ($p = .01$). At the same time, maximal passive dorsiflexion was increased ($p = .005$) and passive stiffness indexes at 10°, 15° and 20° dorsiflexion decreased ($p < .001$; $p < .001$ and $p = .011$, respectively). Tendinous reflex also significantly decreased. As the triceps surae parameters are diminished after the vibration program, it could be beneficial to immobilized persons as hypo-activity is known to increase muscular stiffness.

1. Introduction

Disuse is known to alter the muscle comportment, especially by causing mass and strength reductions (Edgerton and Roy, 1996; Fitts et al., 2000) and by increasing passive and active muscle stiffness (Heerkens et al., 1986; Akeson et al., 1987; Chesworth and Vandervoort, 1995; Lambertz et al., 2001). To prevent muscle deconditionning in the presence of hypo-activity, we previously proposed an Achilles tendon vibration program as a possible muscle conditioning method (Lapole and Pérot, 2010). Tendon vibration stimulates muscle spindle primary endings and causes involuntary repeated muscle contractions via tonic vibration reflexes (Eklund and Hagbarth, 1966; Brown et al., 1967; Burke et al., 1976). We reported that 14 days of such daily vibrations led to significant triceps surae strength gains related to better activation capacities (Lapole and Pérot, 2010). Those results, obtained on healthy subjects, are very interesting in the perspective of applying this vibration program to hypo-active subjects. Furthermore, knowing that muscle stiffness changes may contribute to force changes, it can be asked whether this program can modify muscle stiffness both in active and passive conditions. Considering the muscle model, the muscle elastic comportment can be decomposed into two parts: a series elastic component and a parallel elastic component (Hill, 1938; Shorten, 1987).

The series elastic component (SEC) is known to adapt its characteristics, especially its stiffness, i.e., the musculo-tendinous stiffness, to the functional demand (Pousson et al., 1990). Although whole-body vibration is now commonly used (Luo et al., 2005) the effects of vibration training on musculo-tendinous stiffness have not been well studied yet. Only one animal study reported that vibration training failed to induce mechanical changes on rats' Achilles tendons (Legerlotz et al., 2007). Musculo-tendinous stiffness in humans can be assessed in active conditions by means of a quick-release test (Goubel and Pertuzon, 1973; Cornu et al., 1998; Cornu and Goubel, 2001; Lambertz et al., 2003a,b). Such a test could be used to inform the possible changes of musculo-tendinous stiffness after a vibration program. The parallel elastic component (PEC), responsible for muscle passive tension, can also

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adapt with training (Kovanen et al., 1984; Kovanen, 1989; Gosselin et al., 1998). Passive tension is often characterized by the measure of flexibility, defined as the range of motion about a joint (Tardieu et al., 1981; Guissard and Duchateau, 2004). After different vibration training protocols, associated or not with stretching exercises, many authors reported an enhancement of articular flexibility (Nazarov and Zilinsky, 1984; Issurin et al., 1994; Fagnani et al., 2006; Sands et al., 2006). To understand these adaptations better, it could be relevant to determine muscle passive stiffness. Thus, a flexibility test performed as proposed by Moseley et al. (2001) could inform us on the possible changes in passive stiffness.

Therefore, the aim of the present study is to analyze the effects on healthy subjects of a 2-week Achilles tendon vibration program on triceps surae stiffness, both in active (musculo-tendinous stiffness assessed by a quick-release test) and passive (passive stiffness assessed by a flexibility test) conditions. The effects of the vibration program will also be analyzed on the tendinous reflex (*T* reflex) evoked by the mechanical percussion of the Achilles tendon knowing that this tendon jerk is partly influenced by the stiffness of the elastic structures in series with muscle spindles (Rack et al., 1983). To assess the eventual link between changes in stiffness and changes in *T* reflex amplitude, the Hoffmann reflex (H_{max}), which represents the central influences on reflex excitability, will be also quantified.

If muscle stiffness is diminished by the direct vibration of the Achilles tendon, this tendon vibration program could be useful to prevent muscle stiffening in hypo-active subjects, even in subjects immobilized by plaster cast (thanks to a small window into the cast). During such immobilizations, it has been reported that a tendon program resulted in an increase of the articulation flexibility and a faster re-education compared with traditional therapy (Neiger et al., 1986).

Fig. 1. Ergometric device and its foot-plate in seated (A) and supine (B) positions.

2. Methods

2.1. Subjects

For this study, 19 healthy and active voluntary students (age: 21.7 ± 1.6 years, mass: 71.2 ± 11.2 kg, height: 177 ± 8 cm, calf circumference: 36.4 ± 2.7 cm) of the University de Picardie Jules Verne (Amiens, France) and the Technologic University of Compiègne (France) engaged in the biomechanical testing. Written informed consent was provided by the subjects and they were fully advised of the procedures, and free to stop the experiment at any time. The experimental procedures were approved by the local Ethics committees of the Universities of Amiens and Compiègne, France. The procedures were also approved by the Committee on Person Protection of Picardie.

2.2. Ergometric device

The ankle-ergometer used was a folding and transportable ergometer device (Bio2M-France) developed to measure external torque of the plantar-flexor muscles (Khider et al., 2008) (Fig. 1). The ergometer structure was compliant to subjects with different morphology characteristics, and was positioned in a standard fashion to ensure repeatability and comparability between measurements. A force transducer (S-type load cell, maximal force 500 N, sensitivity 0.5 N) connected at the end of the footplate carried out force measurements during voluntary contractions. A 13-bit absolute optical encoder (GA241, IVO) was fixed within the rotation axis of the footplate providing the measurement of angular position and its derivatives. A holding magnet (Mecalectro, 58201) was connected between the force transducer and the footplate and allowed the release of the footplate when switched off (Fig. 2).

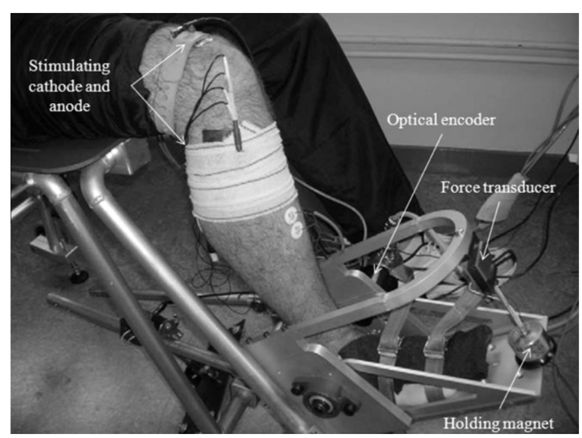

Fig. 2. Foot-plate of the ergometric device with the force transducer, the optical encoder and the holding magnet. The cathode of the stimulating apparatus was placed in the popliteal fossa and the anode on the distal part of the thigh, proximal to the patella. Tendinous mechanical percussions were applied to the Achilles tendon. Surface electrodes were placed on each part of the triceps surae.

Data were sampled using a 12-bit analog/digital board. A dual-beam oscilloscope gave the subject visual feedback on the procedure in progress.

2.3. EMG recording

To detect surface electromyograms (EMG), bipolar Ag/AgCl surface electrodes (83060TXIBC15, Dorvit Medical, 10 mm in diameter, spaced 22 mm center-to-center) were placed on each part of the triceps surae muscle group: over the belly of the gas-