The effects of an eccentric training on the evoked M response and on the related twitch torque of the plantar-flexor muscles

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Introduction

The modifications induced by an eccentric training can be attributed to both peripheral factors (e.g. contractile changes) and/or central factors (e.g. neural adaptations) (Colson et al. 1999). The peripheral changes could be essentially expressed by a selective adaptation of the fast twitch motor units, which are preferentially solicited during eccentric actions. The central factors were instead related to a modification of the electromyographic (EMG) activity of the agonist (Häkkinen 1983 and 1985), but also of the antagonist muscles (Carolan and Cafarelli 1992). A method used to distinguish central vs. peripheral adaptations consists of recording the mechanical and electrophysiological responses obtained under voluntary and electrical stimulation on the motor nerve. This method induces muscle contraction with no influence from central factors, therefore providing information concerning the peripheral origin of adaptations by the analysis of muscle excitation-contraction coupling and contractile kinetics.

The aim of the present investigation was to study the effects of an eccentric training performed over a 4-wk period, on the plantar-flexor nervous and muscular properties. In order to differentiate the relative contribution of central and peripheral adaptations to potential torque gains, the torque and the EMG activity of agonist and antagonist muscles were recorded during maximal voluntary contractions and during electrical stimulation of the motor nerve.

Method

The experiment was carried out on 14 male students divided into two groups: the control group (CG), composed of six subjects (mean age ± SD 26 ± 5.1 years; height 176.7 ± 4.8 cm; mass 69.5 ± 4.6 kg), and the eccentric group (EG), composed of eight subjects (age 23.1 ± 5.2 years; height 175.6 ± 3.8 cm; mass 73.4 ± 10.0 kg). The eccentric group performed sixteen training sessions, each composed of six sets of six eccentric muscle actions at 120% of their one maximal concentric repetition. During training, eccentric contractions were realised on a sitting calf machine. Before and after the training period, two testing sessions were performed. During the first testing session, the maximal isometric torque (MVC) at an ankle angle of 90° of flexion, as well as maximal concentric and eccentric torque at an angular velocity of 60°s⁻¹ were recorded by using an isokinetic dynamometer (Biodex Shirley Corporation, NY, USA). For concentric and eccentric actions, the range of motion was 50°, i.e. 20° in dorsi-flexion and 30° in plantar-flexion. During the second testing session, the posterior tibial nerve was stimulated in the poplitea fossa (rectangular pulse, 9 ms duration) and the peak-to-peak amplitude of the EMG maximal Mwave (Mmax), corresponding to the recruitment of all muscle motor units, was recorded. The related plantar-flexor peak twitch torque (Ptmax) was also analysed. In addition, the maximal rate of twitch tension development (RDp), the maximal rate of twitch tension relaxation (RRp), (respectively the highest and the lowest value of the first derivative of the force signal) and the contraction time (CT) (the time to twitch maximal force, calculated from the origin of the mechanical signal) were measured. During the same sessions, a 250-ms tetanos was also electrically induced at a frequency of 100 Hz at the stimulation intensity used to evoke Mmax.

During the two testing sessions EMG data were collected from soleus (SOL), gastrocnemius medialis (GM), gastrocnemius lateralis (GL) and tibialis anterior (antagonist) muscles, together with the associated plantar-flexor torque.

Results

Before training no significant differences have been found between EC and CG for all parameters. After the 4-wk eccentric training, MVC and maximal eccentric torque significantly increased (p≤0.01) respectively from 89.7±9.5N·m to 115.7±13.5 N·m, and from 147.8±9.7 N·m to 175.7±14.4 N·m, while no significant changes were observed for the concentric torque. This result was related to an increase in
SOL et GM EMG activity, more particularly in eccentric and isometric actions (Fig. 1). The level of coactivation during eccentric and concentric contractions was affected by the eccentric training. Indeed, the tibialis anterior EMG activity significantly decreased in eccentric action by 22% (p=0.05), and concentric by 13% (p<0.05), while no modification was observed in isometric contractions, although a trend was observed (p=0.06).

![Fig. 1: Normalised electromyographic activity (EMG), for soleus (SOL), gastrocnemius medialis (GM) and gastrocnemius lateralis (GL), during eccentric (-60°s⁻¹), isometric (0°) and concentric (60°s⁻¹) contraction, in EG and CG before and after training. Values are mean ± SE. * Significantly higher than pre-training at p<0.05.](image)

No modification of the SOL and GM M_{max} were observed, but with an increase of the GL peak-to-peak amplitude. The twitch contractile properties (Pt, RD_{Pt} and RR_{Pt}) significantly increased with no modification of CT (Table 1). The overall characteristics (P_{0}, RD_{p0}, RR_{p0}) of the torque evoked by 100-Hz tetanic stimulation were unchanged after the 4-wk of eccentric training, but the MVC/tetanos torque ratio significantly raised.

<table>
<thead>
<tr>
<th></th>
<th>Pt_{max} (N.m)</th>
<th>CT (ms)</th>
<th>RD_{Pt} (N.m.ms⁻¹)</th>
<th>RR_{Pt} (N.m.ms⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EG</td>
<td>Before</td>
<td>14.6±1.6</td>
<td>131.9±4.0</td>
<td>0.21±0.02</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>17.4±1.6*</td>
<td>131.4±3.3</td>
<td>0.25±0.03*</td>
</tr>
<tr>
<td>CG</td>
<td>Before</td>
<td>17.4±1.5</td>
<td>136.0±3.8</td>
<td>0.24±0.02</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>16.3±2.3</td>
<td>135.1±3.9</td>
<td>0.24±0.04</td>
</tr>
</tbody>
</table>

Table 1: Twitch contractile properties, obtained before and after training for the eccentric group (EG) and control group (CG). * Significantly higher than pre-training values at p<0.05.

**Discussion and conclusion**

The aim of the present investigation was to study the effects of 4-wk eccentric training on the plantar-flexor torque and to examine the associated central and/or peripheral changes. The present training was an effective stimulus to develop maximal eccentric (mean ± SE gain 19±6%), and isometric
(30±8\%) torque. In the present study, the greater torque gains were observed in isometric conditions. This result could be explained by the slow velocity adopted during training, since the subjects realised the eccentric contractions at a velocity ranging from 15 to 20°·s⁻¹.

Torque production capacity is influenced by several factors. For instance, it has been demonstrated that torque increases resulting from strength training could be related to central adaptations, i.e. modification of the activity of agonist and/or antagonist muscles (Häkkinen, and Komi 1983, Carolan and Cafarelli 1992), and/or peripheral adaptations, i.e. modifications affecting the muscular structure and/or intramuscular processes (Duchateau, and Hainaut 1984). In the present study, the EMG of the plantarflexor muscles increased and the coactivation decreased. These central adaptations, notably on the SOL and GM muscles, could principally explain the torque gains observed here. Indeed, the increases in normalised EMG activity and voluntary torque were strictly concomitant in isometric and eccentric conditions. Moreover, the coactivation level showed a tendency to decrease. The modifications of the twitch parameters (Pt, RDₚᵣ and RRₚᵣ) reflected changes occurring at the peripheral level and involving intramuscular mechanisms located beyond the membrane, which could be associated at Ca²⁺ movements. Because no significant changes in CT were observed, the improved excitation-contraction coupling cannot be related to a prolongation, but rather to an intensification of the contractile protein activation. However, these modifications were not associated to changes in tetanic torque and the others tetanic parameters. As a matter of fact, the intramuscular modifications noted by the analysis of the single twitch cannot explain alone the present voluntary torque gains, which could be related more particularly to central adaptations.

It can be concluded, that our eccentric training was a valid stimulus to increase isometric and eccentric torque, and that neural adaptations seems to play a major role in explaining the present torque gains. These latter seemed instead more related to neural adaptations affecting myoelectrical activity of both agonist and antagonist muscles. This result seems also confirmed by the increased MVC/tetanos ratio observed after training.

References


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