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Effects of electromyostimulation versus voluntary isometric training on elbow flexor muscle strength

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Abstract

The purpose of this study was to determine whether 7 weeks of standardized (same number and duration of repetitions, sets and rest strictly identical) electromyostimulation training of the elbow flexor muscles would induce strength gains equivalent to those of voluntary isometric training in isometric, eccentric and concentric contractions. Twenty-five males were randomly assigned to an electromyostimulated group (EMS, $n = 9$), a voluntary isometric group (VOL, $n = 8$), or a control group (CON, $n = 8$). Maximal voluntary isometric, eccentric and concentric strength, electromyographic (EMG) activity of the biceps and triceps brachii muscles, elbow flexor muscle activation (twitch interpolation technique) and contractile properties were assessed before and after the training period. The main findings were that the isometric torque gains of EMS were greater than those of VOL after the training period ($P < 0.01$) and that the eccentric and concentric torque gains were equivalent. In both groups, we observed that the mechanical twitch (Pt) was increased ($P < 0.05$) and that torque improvements were not mediated by neural adaptations. Considering the respective intensities of the training programs (i.e., submaximal contractions for EMS versus maximal for VOL), it can be concluded that electromyostimulation training would be more efficient than voluntary isometric training to improve both isometric and dynamic strength.

Keywords: Strength gains; Muscle activation; M_{max}; Twitch contractile properties; Isokinetic

1. Introduction

Electromyostimulation is generally used to improve the maximal voluntary strength of weakened and/or healthy muscles. After multiple training sessions, many authors have demonstrated its effectiveness in sports medicine (Steadman, 1982), geriatric medicine (Caggiano et al., 1994), physical therapy (Gould et al., 1982), and the treatment of neuromuscular diseases (Scott et al., 1986). Electromyostimulation for rehabilitation purposes is usually conducted in isometric conditions and specific isometric strength improvements have been observed (Bax et al., 2005), although data are sparse regarding dynamic strength, which is needed mainly in the movements of daily living activities. It therefore remains unclear whether electromyostimulation is more efficient than voluntary isometric training to improve strength production in both isometric and dynamic conditions (eccentric and concentric).

Several studies have reported that voluntary isometric training results in specific adaptations (i.e., strength increases are specific not only to the joint angular position used during training sessions but also to the isometric contraction mode) (Thorstensson et al., 1976; Kitai and Sale, 1989; Weir et al., 1995). However, other studies (Behm and Sale, 1993; Rich and Cafarelli, 2000; Maffiuletti and Martin, 2001) have reported that this type of training can also improve dynamic strength production (i.e., eccentric

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and concentric contraction modes). These latter studies suggest that both isometric and dynamic strength gains probably occur after voluntary isometric training.

Interestingly, some authors have observed that an electromyostimulation training program carried out in isometric conditions can increase both isometric and dynamic strength (Martin et al., 1993; Pichon et al., 1995; Colson et al., 2000). This nonspecificity of the isometric contraction mode in training sessions might be ascribable to the nonselective recruitment of motor units (i.e., a partial reversal order as compared with voluntary contractions) (Solomonow, 1984; Knaflitz et al., 1990; Feiereisen et al., 1997; Gregory and Bickel, 2005). Thus, a difference in strength gains could also be expected between electromyostimulation and voluntary isometric training (i.e., identical isometric muscle contraction but different motor unit recruitment). In addition, recent reports about hybrid muscle activation (i.e., electromyostimulation superimposed onto voluntary contraction) have demonstrated that the muscle strength produced during a muscle contraction induced by electromyostimulation is also dependent of the central nervous system (Langzam et al., 2006, 2007). Although several authors have attempted to determine which is the more efficient stimulus to improve muscle strength (Eriksson et al., 1981; Gould et al., 1982; Selkowitz, 1985; Miller and Thépaut-Mathieu, 1993), surprisingly, only one study compared standardized submaximal electromyostimulation and voluntary isometric training protocols (Duchateau and Hainaut, 1988). These authors concluded that electromyostimulation was less efficient and served as a complement to voluntary isometric training, but they only assessed isometric strength. Moreover, they did not provide sufficient evidence to guide decisions on the type of training that should be, for example, chosen in the context of rehabilitation. Indeed, the study provided no information about the impact of electromyostimulation and/or voluntary isometric training on the dynamic muscle contractions that typically occur during daily living activities.

The aim of the present study was to investigate the effects of 7 weeks of electromyostimulation versus 7 weeks of voluntary isometric training on both the isometric and dynamic strength (eccentric and concentric) of the elbow flexor muscles. In order to assess the neural and/or peripheral adaptations induced by the two forms of training, surface electromyography of agonist and antagonist muscles, contractile properties and the activation level of the elbow flexor muscles were also investigated. This study presents an original training setting in which the training protocols were standardized for both the electromyostimulation and the voluntary conditions (i.e., both performed with isometric contractions, same number and duration of repetitions, sets and rest strictly identical). Given these standardized conditions and the difference in motor unit recruitment, it was hypothesized that standardized electromyostimulation training would induce isometric and dynamic strength gains equivalent to those of voluntary isometric training.

2. Methods

2.1. Subjects

Twenty-five male volunteer subjects provided informed written consent to participate in the investigation. They were randomly assigned to an electromyostimulation training group (EMS; $n = 9$, age 24 ± 2.5 years, height 179.1 ± 5.4 cm, weight 74.9 ± 6.4 kg), a voluntary isometric training group (VOL; $n = 8$, age 22.9 ± 3 years, height 178.8 ± 7.8 cm, weight 79.4 ± 8.9 kg), or a control group (CON; $n = 8$, age $= 20.6 \pm 2.2$ years, height 178.4 ± 7.2 cm, weight 76.8 ± 6.3 kg). None had previously engaged in systematic strength training or high-level sports practice. The study was conducted according to the Declaration of Helsinki and approval for the project was obtained from the University of Burgundy committee on human research.

2.2. Training programs

Subjects of EMS and VOL unilaterally trained their right elbow flexor muscles in isometric conditions for 7 weeks, with three sessions per week. Training in both groups was standardized (identical in time, duration, and contractions) and consisted of 21 sessions of isometric contractions performed in either electromyostimulated or voluntary conditions at an elbow angle of 90°. Thirty (5 sets $\times$ 6 repetitions) isometric contractions were carried out during each training session. Within a set, the duration of each action lasted 6 s and a 3-s interval was allowed between each repetition. Each set was repeated every 3 min. One day of rest was allowed between training sessions during the week, with 2 days of rest over the weekend. Each training session was preceded by a standardized warm-up consisting of 5 min (10 s of contraction following by 20 s of rest) of submaximal voluntary isometric flexions with a load corresponding to 50% of the maximal load that each subject was able to lift concentrically.

2.2.1. Electromyostimulation training

The subjects of EMS trained with a portable battery-powered stimulator (Compex 2®, Compex Medical SA, Ecublens, Switzerland) which delivered electrical stimulation. Three 2-mm thick, elastomer-type, self-adhesive electrodes were applied over the belly of the biceps brachii muscle. The negative electrode measuring 50 cm^2 (10×5 cm) was placed 7–9 cm below the acromion and perpendicularly to the line formed between the medial acromion and the cubital crease when the elbow was flexed at 90°. Two positive electrodes measuring 25 cm^2 (5×5 cm) were placed on either side of this line and as close as possible to the negative electrode. Rectangular-wave pulse currents (80 Hz) lasting 240 μs were delivered to the subjects and the intensity, monitored online, was gradually increased throughout the training session to maximally tolerated intensity, which varied between 70 and 120 mA, depending on the individual pain threshold. During the stimulation, subjects were asked to relax and the elicited isometric torque corresponded to 60–70% of their maximal voluntary isometric torque. No subject reported serious discomfort. The stimulation characteristics of the present training were selected according previous recommendations (Hainaut and Duchateau, 1992).

2.2.2. Voluntary isometric training

The subjects of VOL trained with a load equal to 100% of the individual one maximum repetition (1MR), the maximal load that each subject was able to lift concentrically only once (from full