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On the effect of thermal agents in the response of the brachial biceps at different contraction levels

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ABSTRACT

The objective of this study was to assess electromyographic features of the brachial biceps muscle after the application of cryotherapy and short-wave diathermy. Sixty healthy volunteers participated in the study and were equally divided into three groups: cryotherapy – application of ice packs for 30 min; short-wave diathermy for 20 min; and control. The thermal agents were applied to the anterior and posterior regions of the non-dominant arm. The electromyographic (EMG) signal from the brachial biceps was recorded before and after the application of thermal agents during flexion of the elbow joint at 25%, 50%, 75% of a maximum voluntary isometric contraction defined at least two days before the actual experiments ($MVIC_{bl}$). The volunteers also were asked to execute a free MVIC before and after the application of the thermal agents ($MVIC_{free}$). A linear regression model with mixed effects (random and fixed) was used. Intra-group analysis showed a reduction in root mean square (RMS) at $MVIC_{free}$, with no change in the median frequency of the EMG signal at any contraction level for the short-wave diathermy group. An increase on RMS values and a decrease on median frequencies were found after the application of cryotherapy for all contraction levels. The results imply that cryotherapy plays an important role on changing neuromuscular responses at various levels of muscle contraction. Therapists should be aware of that and carefully consider its use prior to activities in which neuromuscular precision is required.

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1. Introduction

In physiotherapy clinical practice, it is very common to use thermal agents, such as cryotherapy (CR) and short-wave diathermy (SWD), prior to performing exercises at different levels of muscular contraction.

The cryotherapy decreases skin and muscle temperature (Rupp et al., 2012) and when applied before exercises, may result in inadequate peripheral feedback on the position sense and may change biomechanical properties of the joint (Hopper et al., 1997; Uchio et al., 2003). SWD is a deep heat modality, which can reach the muscle tissue (Garret et al., 2000), but its effect on the mechanical function of active musculotendons is not well understood (Mitchell et al., 2008). If neuromuscular function is compromised in both treatments, injury may occur when exercise is performed (Khanmohammadi et al., 2011).

Most of the studies found in the literature assessed the effects of changes in temperature during a maximum voluntary isometric contraction (MVIC) (Dewhurst et al., 2010; Stewart et al., 2003; Pereira et al., 2010, 2011; Kimura et al., 2003; Cahill et al., 2011; Racinais et al., 2008; Madigan and Pidcoe, 2002), and few have evaluated those effects during submaximal contractions (Mitchell et al., 2008; Coulange et al., 2006; Meigal et al., 1998; Rubley et al., 2003; Oksa et al., 2002), which characterize the daily life activities.

Considering the scarcity of studies that relate the SWD with the electromyographic signal and the lack of proper findings on the changes of muscular response induced by changes in temperature prior to performing maximal and submaximal exercises, the authors decided to study the behavior of EMG features (signal amplitude and frequency response) of the brachial biceps muscle (BB) after the application of cryotherapy or short-wave diathermy at different levels of MVIC during flexion of the elbow joint. The hypothesis raised here is that the application of thermal agents can change electromyographic signal amplitude and frequencies of the BB in a broad range of contraction levels. Verifying such

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hypothesis would be of great importance to current physical rehabilitation programs that usually associate CR with muscular training.

2. Materials and methods

2.1. Sample

Sixty-four university female volunteers were selected according to the following inclusion criteria: age 18–30 years old; body mass index (BMI) between 20 and 25 kg/m^2; no metabolic diseases, skin lesions or fractures in upper limbs; no contraindication for cryotherapy and/or SWD; and not being in premenstrual or menstrual period so that hormonal influence can be controlled (Dewhurst et al., 2005; Charkoudian et al., 1999). This project has been approved by the local Research Ethics Committee (protocol N.625/2009).

The volunteers were randomly and equally divided into three groups ($n = 20$): control group (CG), short-wave diathermy group (SWG) and cryotherapy group (CRG). Table 1 shows the anthropometric data and ages. Four volunteers left the study due to schedule incompatibility.

2.2. Instrumentation

2.2.1. Electromyograph

All instruments used in the study were carefully calibrated before data collection according to the instructions listed in the manufacturer's guide. In order to minimize possible power line interferences, all electronic devices were powered by a 12 V 40 Ah battery (Guirro et al., 2006). Before and during data collection the EMG signal was monitored via the software interface (Aqdados 7.02, Lynx® Tecnologia Eletrônica, São Paulo, Brazil).

The signal acquisition module (EMG-1000, Lynx® Tecnologia Eletrônica, São Paulo, Brazil) was connected to a netbook (Acer® Aspire One1Gb) by means of an optical fiber in order to minimize interference. Data collection was performed in an acclimatized room with controlled temperature (23 °C ± 2°) and illuminated with incandescent lamps.

The signal acquisition module has impedance of 10^9 ohms and 16-bit resolution, sampling rate of 2000 Hz, high-pass filter of 20 Hz and low-pass filter 1000 Hz.

EMG signals were captured by using a single differential surface sensor (Lynx® Tecnologia Eletrônica, São Paulo, Brazil) made of two silver bars of 10-mm length × 1-mm width each, positioned in parallel and separated by 10 mm. The sensor also had a 20× pre-amplifier circuitry (±1%), common mode rejection rate (CMRR) >100 dB, and signal noise rate <3 μV (RMS). The reference electrode was made of stainless steel with dimensions of 4 × 3 cm, positioned on the acromion of the homolateral limb with electro-conducting gel.

Table 1
Age and anthropometric data for the control (CG), short-wave diathermy (SWG) and cryotherapy (CRG) groups ($n = 20$). Values expressed in terms of mean ± standard deviation.

	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)
CG	24 ± 3.83	1.65 ± 0.07	60.44 ± 7.52	22.07 ± 1.91
SWG	21.85 ± 2.13	1.65 ± 0.07	58.47 ± 7.15	21.51 ± 2.01
CRG	22.4 ± 2.28	1.64 ± 0.07	58.02 ± 6.77	21.56 ± 1.7

No significant differences were observed in anthropometric data and age between groups.

2.2.2. Force

The force was measured by means of a load cell (MM-50 Kratos®, São Paulo, Brazil), positioned perpendicularly between the distal third of the forearm and the floor.

2.2.3. Short-wave device

A thermowave device (BIOSET® – certified by ANVISA 10360310010, Brazil) was used for the application of short-wave diathermy operating at a frequency of 27.12 MHz, in continuous mode and maximum power of 200 W.

2.2.4. Temperature

The skin temperature over the brachial biceps muscle was recorded during data acquisition by means of a digital infrared thermometer (Incoterm®, Porto Alegre, Brazil).

2.3. Experimental procedure

After being submitted to the initial evaluation and included in the study, the volunteers were asked to perform maximum voluntary isometric contractions (MVIC) of the non-dominant flexor muscles, during which EMG and force were acquired simultaneously, in order to define the MVIC baselines ($MVIC_{bl}$) for each volunteer. The $MVIC_{bl}$ was defined by the average of six MVICs, performed during 6 s with 60 s interval, except between the third and forth repetitions, when the volunteer was allowed to rest for 5 min. The volunteers were verbally encouraged during the process. Data recording started 2 s after muscle contraction, when force levels were stable.

After a minimum interval of 48 h (Mitchell et al., 2008; Ruiz et al., 1993), the volunteers returned to the laboratory for the next stage of data collection (before and after the application of therapeutic agents).

To capture the EMG signals from the brachial biceps muscle of non-dominant arm, the sensor was positioned according to specifications defined by the SENIAM project (Hermens et al., 2000), fixed to the volunteer's skin with hypoallergenic tape (Micropore® TM) and wrapped with an elastic band to improve contact as well as minimize movement. The skin was prepared by means of trichotomy and cleaning with alcohol 70%. During data collection, the volunteers were positioned on a Bonet table with head and shoulders in neutral position, trunk stabilized with inelastic bands, elbow kept at 90° angle and rested on a support. The forearm remained in neutral position, with its mid-third involved by a cuff connected to the load cell perpendicularly to the floor.

The volunteers were first asked to perform too types of contractions: (a) isometric elbow flexion contraction at 25%, 50%, 75% of $MVIC_{bl}$, during which a visual force feedback was provided on a computer screen to help them maintain the required force levels; and (b) a free MVIC ($MVIC_{free}$). The order was randomly defined. Three contractions were required for each level of force.

The electromyographic (EMG) signal from the brachial biceps, the force and the temperature of the skin over the brachial biceps muscle were recorded before and after the application of the thermal agents.

Upon completion of the first set of data collection, the EMG sensor and the reference electrode were removed for the application of the therapeutic agent, except for the volunteers of the control group that remained at rest for 30 min. SWG volunteers were submitted to 20 min of short-wave diathermy, operating in a continuous and capacitive mode at 120 W (±10%), by means of two standard electrodes (18 × 13 cm), one being positioned on the brachial biceps and the other on the brachial triceps, both isolated from the skin by a rigid felt layer. SWG volunteers reported sensations of light to mild heat intensity. For the CRG volunteers, two plastic packs containing 1.5 kg of grinded ice each (Merrick et al.,

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