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EMG amplitude and frequency parameters of muscular activity: Effect of resistance training based on electromyographic fatigue threshold

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Abstract

The present study aimed to evaluate the effect of a resistance training program based on the electromyographic fatigue threshold (EMG_{FT}, defined as the highest exercise intensity performed without EMG alterations), on the EMG amplitude (root mean square, RMS) and frequency (median frequency, MF) values for biceps brachii (BB), brachioradialis (BR), triceps brachii (TB) and multifidus (MT). Twenty healthy male subjects, (training group [TG], $n = 10$; control group [CG], $n = 10$), firstly performed isometric contractions, and after this, dynamic biceps curl at four different loads to determine the EMG_{FT}. The TG training program used the BB EMG_{FT} value (8 weeks, 2 sessions/week, 3 exhaustive bouts/session, 2 min rest between bouts). No significant differences were found for the isometric force after the training. The linear regression slopes of the RMS with time during the biceps curl presented significant decrease after training for the BB, BR and TB muscles. For the MT muscle, the slope and MF intercept values changed with training. The training program based on the EMG_{FT} influenced EMG the amplitude more than EMG frequency, possibly related to the recruitment patterns of the muscles, although the trunk extensor muscles presented changes in the frequency parameter, showing adaptation to the training program.

Keywords: RMS; Median frequency; EMG_{FT}; Resistance exercise; Training

1. Introduction

Dynamic resistance training provides increases on the muscular force output and hypertrophy (Hubal et al., 2005; McCall et al., 1996). These alterations have been followed by increases in the electromyographic (EMG) amplitude during maximum contractions (Colson et al., 1999; McBride et al., 2003; Pousson et al., 1999) while the frequency parameters remain unchanged (Macaluso et al., 2000). In spite of the important information that EMG offers about training effects, there is a lack of information regard to the use of an EMG index for training load prescriptions, particularly to the electromyographic fatigue threshold (EMG_{FT}). This index is based on the EMG *vs* time slope values at different load levels, and it is defined as the intensity in which someone can perform the exercise for the longest time without changes in the EMG activity (Cardozo and Gonçalves, 2003; Housh et al., 1995; Oliveira et al., 2005; Pavlat et al., 1993). The EMG_{FT} have been correlated with physiological index commonly used to endurance training, as the anaerobic threshold (Matsumoto et al., 1991; Moritani et al., 1993). On practice, it can be suggested that the EMG_{FT} may provide an attractive alternative for endurance prediction, based in the changes of the motor unit recruitment at different load levels.

Considering the muscle adaptations to resistance training, a positive effect on force and hypertrophy have been found in antagonistic muscles during agonist training

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(Pousson et al., 1999). A transfer has also been shown in the EMG activity, as observed for the EMG decrease of the triceps brachii (TB) muscle after elbow flexion training (Pousson et al., 1999). Furthermore, there was a great transfer of EMG activity to hip muscles during trunk extensions (Clark et al., 2003). Nielsen et al. (1998) found that the higher the height of load application, the more trunk extensor muscles EMG activity increase. More recently, Oliveira et al. (2006) verified increases in the trunk extensor EMG activity over the time course of adapted biceps curl exercise (ABC), advising apprentices that the lumbar area presents important activation during exercises performed in standing position. This could lead to resistance training effects, even though the training is not focused in the lumbar area.

It is hypothesized that force and EMG could be increased in the elbow flexors muscles, using the EMG_{FT} as endurance training index. Therefore, possibly antagonistic triceps brachii and the lumbar extensor muscles could present decreases in the EMG activity after the training period. In this context, the aim of the present study was to evaluate the effect of resistance training, based on the EMG_{FT} of the biceps brachii muscle, on the amplitude and frequency parameters of the agonists (BB and BR), antagonistic (TB) and trunk stabilizing muscles (MT) in isometric and dynamic contractions.

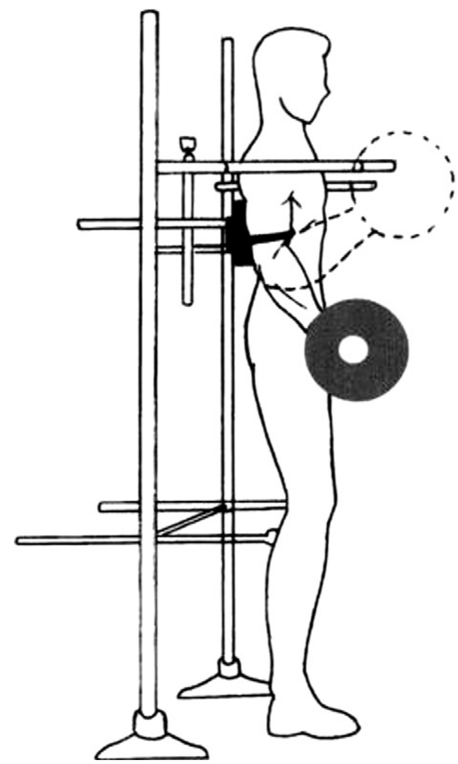

Fig. 1. Experimental setup for adapted biceps curl exercise.

2. Methods

2.1. Subjects

Twenty healthy men (mean ± SD age 21 ± 1.3 years, height 176.2 ± 4.7 cm, body mass 72.1 ± 7.8 kg) volunteered to participate in the present study. Although physically active, all subjects were considered untrained and had not participated in a regular exercise program for the last 6 months prior to the study, and were told to maintain their normal daily activities throughout the investigation period. All subjects were informed of the procedures, the risks and benefits associated with the participation in the study and signed an informed consent term previously approved by the Local Ethics Committee.

2.2. Design

Subjects were randomly divided in two groups in this study. A training group [TG, $n = 10$, mean ± SD age 21.2 ± 1.2 years, height 174.4 ± 5.5, body mass 70.48 ± 7.73 kg], and a control group [CG, $n = 10$, mean ± SD age 20.8.2 ± 1.4 years, height 177.9 ± 3.9, body mass 73.7 ± 7.8 kg], The subjects were tested throughout 12 weeks, and in the first week they performed the dynamic one repetition maximum (1RM) determination in the biceps curl exercise. On each day of testing, the subjects initially performed stretch exercises for the elbow and shoulder muscles, followed by a warm up of 30–60 s ABC exercise, to adapt to the rhythm and positioning.

The next week, the EMG_{FT} determination was performed in ABC exercise using a straight bar (2 kg) and plate weights (0.5 kg, 1 kg, 4 kg, 5 kg and 10 kg), and a metallic stem system equipment (Oliveira et al., 2006; Oliveira and Gonçalves, 2006) (Fig. 1), the purpose of which was to control posture and symmetry, especially the upper limbs movements in the sagital and frontal planes by means of a strap, protected by foams around the elbow joint. This equipment also provided the maintenance of 15° in the knee flexion during the exercise through the contact of the posterior face of the knee to the equipment.

The TG subjects participated in an 8-week endurance training program (weeks 3–10) for the elbow flexor muscles adapted from previous studies (Campos et al., 2002; McBride et al., 2003). Workouts were performed 2 days/week, three bouts of ABC exercise until the subject was unable to maintain the range of motion (ROM) with 2 min rest period between them (Kraemer and Ratamess, 2004). The biceps brachii EMG_{FT} (% 1RM) has been used as the training intensity. At the end of the fourth week, there was the 1RM reevaluation, and the training intensity was readjusted if necessary. The CG was asked not to participate in any resistance training protocol during 8 weeks. After the training period, the test procedures of the two first weeks were repeated for the CG and TG (weeks 11 and 12). Fig. 2 represents the experimental procedures.

2.3. EMG

Surface EMG activity from biceps brachii (BB), brachioradialis (BR), triceps brachii (TB) and multifidus (MT) muscles was recorded by means of two adhesive, pre-gelled silver/silver chloride surface electrodes (MediTrace, 30 mm diameter, 10 mm caption area) during isometric and dynamic contractions. After shaving, abrading and cleaning the skin with alcohol, two electrodes were placed at the distal third of the right arm, in the common portion of the biceps brachii muscle (Hermens et al., 2002); for brachioradialis muscles, on the belly of the muscle,

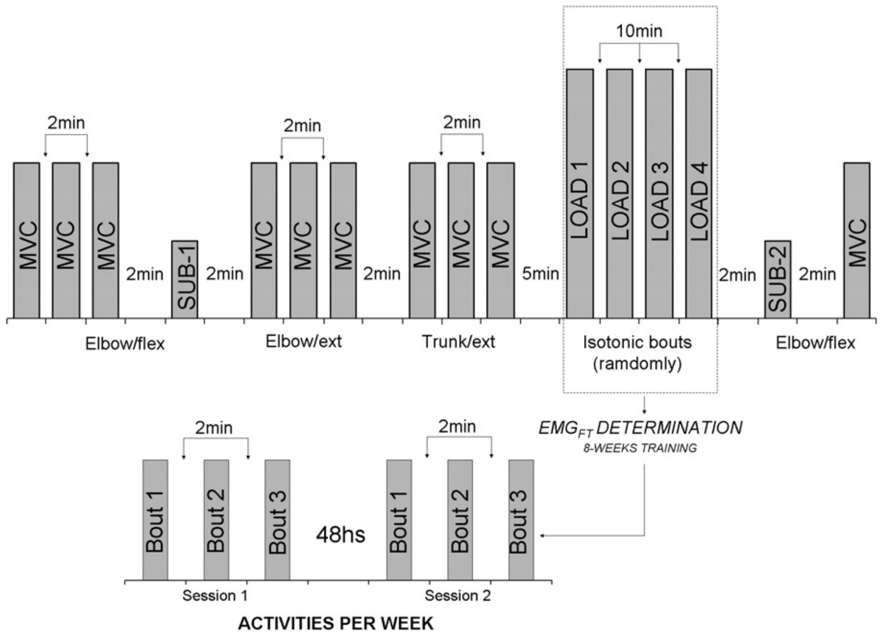

Fig. 2. Experimental procedures, in which subjects performed isometric maximum voluntary contractions (MVC) and submaximal contractions before (SUB-1) and after (SUB-2) the dynamic exercise. After the EMG_{FT} determination, 8-week endurance training for training group was performed.

5 cm distal to the elbow joint (Ervilha et al., 2004); for triceps brachii (lateral head), 50% between acromium of the scapula and the ulna olecranum (Hermens et al., 2002); for multifidus muscle at L4–L5 level, 3 cm laterally (De Foa et al., 1989). The inter-electrode distance was 20 mm. A ground electrode was placed on the wrist. Surface EMG signals were amplified (1.000×), high pass filtered (20 Hz), and low pass filtered (500 Hz). The common mode rejection ratio was 80 dB. The sampling frequency was 4000 Hz, and the EMG data was stored with the force signal on a computer disk. In order to avoid interferences from the local net in the EMG data, a 60 Hz notch filter was used.

2.4. Pre- and post-training tests

2.4.1. One repetition maximum (1RM) test

The maximal dynamic force in the ABC exercise was measured by the 1RM test, using a straight bar (2 kg) and plate weights (0.5 kg, 1 kg, 4 kg, 5 kg and 10 kg). The subjects were positioned in standing position, 1.5 m in front of a mirror (150 cm height, 70 cm width) holding a straight bar keeping forearms in supine position. The initial load was 30 kg. The elbow flexion ROM was to be performed completely, starting from the full extension in order to avoid compensations with shoulders and trunk.

After each valid contraction, 5 kg were added to the bar until the subject was no longer able to perform the contraction in the ROM and/or correct position. At this point of the test, the load was decreased in 1 kg and another attempt was performed. The same procedure was performed until the subject was able to complete a valid attempt, and the 1RM was considered the load used in this attempt. The rest period between contractions was 5 min and a maximum of six contractions were performed. On the day selected to determine the 1RM, the subjects were familiarized with the activities that would be executed at the day of the EMG tests. For familiarization purposes, the subjects performed the dynamic movements receiving instructions on rhythm, posture and ROM, as well as on the execution of the isometric contractions. During the training period, the TG performed a 1RM test at the end of the fourth week of training in order to adjust training loads until the end of the training session.

2.4.2. Isometric maximum voluntary contractions (MVC)

Prior to the dynamic exercises, the subjects performed three 5-s elbow flexion and extension MVCs for the right side, and after, three isometric trunk extension MVCs were performed, with 2-min rest period between contractions. These contractions were performed with the main objective of normalizing EMG data, and comparing with pre-training values. For the elbow flexion and extension MVCs, the subjects were positioned seated on a specific chair developed for the study, with the elbow flexed at 90°, arm along the body and with a strap fixed on the wrist and connected to a strain gauge (Kratos Dinamômetros, MM 200 kgf). Trunk extensions were performed in the same equipment, in seat position (feet with no contact with the ground) and the subjects were stabilized with pelvic and thigh straps. A vest was fixed on the trunk connected to the strain gauge. The highest force value in these three contractions was considered as the MVC. After the third MVC for elbow flexion, a submaximal (50% MVC) isometric elbow flexion was performed, as well as 2 min after the last dynamic bout. To finish the test, a last MVC was performed 4 min after the last dynamic bout with the objective of analyzing the effects of the protocol on the MVC.

2.4.3. Dynamic contractions—EMG_{FT} determination

After the isometric contractions, the subjects performed four bouts of 1 min in ABC exercise. The rhythm was established by means of a metronome (40 bpm). The load levels were 25%, 30%, 35%, and 40% of 1RM randomly selected, with 10 min of rest between them for recovery purposes (Esposito et al., 1998; Kuorinka, 1988; Oliveira and Gonçalves, 2006). During the dynamic bouts, the examiner encouraged the subjects to execute the exercise properly, with verbal orientations in order to avoid alterations in speed and posture.

2.5. EMG analyses

For the EMG analysis, specific algorithms created in MatLab environment were used (The MathWorks, Natick, Massachusetts, USA). The MVC was calculated as the average force over a 1-s period during the force-plateau level. The highest of the three initial MVC was accepted as the MVC for each subject. The raw EMG signal was full rectified, and the amplitude root mean square (RMS) values were obtained, as well as median frequency (MF), by means of spectral analysis, using the power spectral density (PSD) algorithm available in Matlab statistical toolbox. For dynamic contractions, EMG data were recorded during the entire 1-min bouts. For each load level and exercise at every 90° elbow position of concentric contractions were analyzed. These positions were found by means of images simultaneously recorded in the EMG data (JVC GR-AX910U, Tokyo, Japan), and synchronized with EMG data by a photo-electronic trigger (Tortoza et al., 1993). A 250 ms window started at 90° was analyzed for each concentric contraction, and the RMS and MF was calculated using similar processing techniques in isometric contractions. To determine the EMG_{FT} of the biceps brachii and brachioradialis muscles for each exercise, linear regression of the RMS over the time course determined slopes and intercepts for the different load levels. The slope values were then correlated with the load levels and the intercept of these linear regressions were defined as the EMG_{FT} (Cardozo and Gonçalves, 2003). Fig. 3 exemplifies the data processing.

2.6. Statistical analyses

Data are presented as mean ± SD. The comparison of the 1RM (before and after training) was performed using the student paired *t*-test. Comparisons of the maximal isometric contractions (effect of group, training and EMG_{FT} protocol) were performed using a three-way ANOVA for force and EMG of each muscle tested, complemented by the Tukey test. Training-related effects in dynamic RMS and MF slopes and intercepts, for each muscle and load level, were observed using the Mann-Whitney test. Comparisons of EMG_{FT} between muscles (BB × BR in both groups) and training effects on the EMG_{FT} values were performed using the Mann–Whitney test for each muscle. The statistical significance level was set at $p < 0.05$.

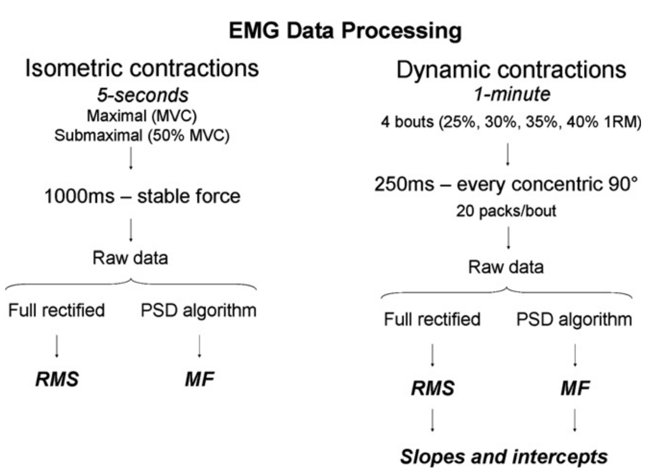

Fig. 3. EMG data processing to isometric and dynamic contractions.

3. Results

3.1. Dynamic strength

Pre-training dynamic strength were 36.10 ± 3.90 kg and 37.30 ± 3.74 kg for CG and TG, respectively at the fifth week; TG 1RM was 38.9 ± 4.18 kg, and it was significantly different after training (39.34 ± 4.3 kg) ($P < 0.05$), increasing 5.9 ± 4.2%. The CG demonstrated no significant changes in 1RM.

3.2. MVC

Elbow extension force were 23.11 ± 2.69 kg and 25.22 ± 1.70 kg for CG and TG, respectively. Trunk extension force values were 91.81 ± 19.06 kg and 101.71 ± 24.46 kg in the beginning of the training, and no significant changes were observed after training either in the elbow extension (22.74 ± 1.70 kg and 23.99 ± 3.34 kg) for CG and TG, respectively or in the trunk extension (98.76 ± 20.36 kg and 99.44 ± 16.69 kg, for CG and TG, respectively) after training.

At the beginning of the training, the elbow flexion force was 28.74 ± 2.09 kg and 29.79 ± 3.63 kg in MVC1 for CG and TG, respectively, and in MVC2 21.77 ± 2.35 kg and 27.49 ± 3.54 kg for CG and TG, respectively. The MVC1 was higher than MVC2 only for CG ($P < 0.05$). After the training period, the MVC1 for CG (29.51 ± 3.01 kg) and TG (30.97 ± 3.03 kg) was not different from the beginning of training, neither MVC2 after training for CG (25.93 ± 3.14 kg) and TG (28.61 ± 2.21 kg). Similarly, RMS and MF presented predominantly no significant differences in MVC1 and MVC2 for both muscles (Fig. 4). After training, the biceps brachii RMS decreased significantly in MVC1 and MVC2 ($P < 0.05$), while the brachioradialis RMS increased ($P < 0.05$) for TG. No significant changes were found in MF for both groups.

3.3. EMG_{FT}

The EMG_{FT} in the pre-training was 31.30 ± 9.70% 1RM and 32.70 ± 9.70% 1RM for BB and BR, respectively, and after training was 29.40 ± 6.03% 1RM and 30.80 ± 6.00% 1RM for BB and BR, respectively for CG. For the TG, EMG_{FT} in the pre-training was 27.53 ± 6.62% 1RM and 29.3 ± 6.04% 1RM for BB and BR, respectively, and post-training was 32.05 ± 4.83% 1 RM and 31.3 ± 5.02% 1 RM for BB and BR, respectively. There were no significant differences in EMG_{FT} between biceps brachii and brachioradialis muscles ($P > 0.05$), between groups ($P > 0.05$), as well as for both groups pre- to post-training ($P > 0.05$), although TG presented

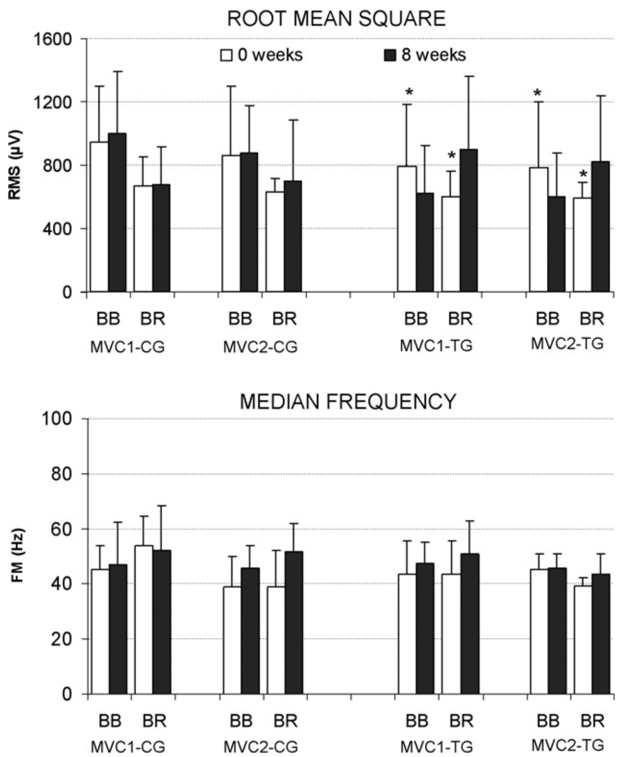

Fig. 4. Biceps brachii (BB) and brachioradialis (BR) root mean square (RMS, *upper*) and median frequency (MF, *bottom*) in maximum isometric contractions before (MVC1) and after (MVC2) adapted biceps curl exercise for control group (CG) and training group (TG) before (0 weeks) and after the training (8 weeks). *Significantly different from 8 weeks in the same muscle.

a tendency to higher EMG_{FT} values after the training period.

3.4. Training effects in the biceps brachii and brachioradialis

Using the biceps brachii EMG_{FT} as load index, the elbow flexion training was conducted during eight weeks for TG, followed by EMG activity reevaluation. No significant differences were found in CG RMS slopes (Fig. 5) after 8 weeks ($P > 0.05$), while for TG significant decreases were found for all load levels ($P < 0.05$). The MF slopes of the BB (Hz s^{-1}) for TG in the pre-training were -0.48 ± 0.73; -0.59 ± 0.47; -0.71 ± 0.66; -0.93 ± 1.04, and post-training were -0.34 ± 0.36; -0.44 ± 0.55; -0.69 ± 0.71; -0.93 ± 1.04 for 25%, 30%, 35% and 40% 1 RM, respectively. For BR, the MF slopes (Hz s^{-1}) in the pre-training were -0.10 ± 0.72; -0.24 ± 1.12; -0.23 ± 0.66; -0.72 ± 0.80, and post-training were -0.39 ± 0.61; -0.28 ± 0.38; -0.44 ± 0.51; -0.56 ± 0.49 for 25%, 30%, 35% and 40% 1 RM, respectively. No significant changes after training for both groups in the MF slopes were verified. The MF intercepts presented no significant changes after training for both groups in RMS (Table 1). The MF intercepts of the BB (%MVC) for TG in the pre-training were 30.21 ± 11.10; 31.32 ± 17.81; 36.81 ± 12.74; 43.24 ± 10.52, and post-training were 24.12 ± 9.92; 26.82 ± 13.08; 28.27 ± 13.63; 36.57 ± 13.37 for 25%, 30%, 35% and 40% 1RM, respectively. The MF intercepts of the BR (%MVC) for TG in the pre-training were 28.18 ± 9.62; 32.29 ± 11.52; 36.77 ± 11.74; 42.88 ± 11.50, and post-training were 23.57 ± 9.36; 28.17 ± 11.89; 31.35 ± 8.88; 34.61 ± 6.52 for 25%, 30%, 35% and 40% 1RM, respectively. No significant changes after training for both groups in the MF intercepts were verified.

3.5. Training effects in the triceps brachii

Interestingly, significant decreases on RMS slopes for the TB muscles after training were observed (except in 35% 1RM, Fig. 5) for TG. The MF slopes (Hz s^{-1}) for TG in the pre-training were -0.35 ± 0.40; -0.32 ± 0.41; -0.25 ± 0.67; -0.29 ± 0.25, and post-training were -0.29 ± 0.31; -0.35 ± 0.48; -0.36 ± 0.30; -0.43 ± 0.30 for 25%, 30%, 35% and 40% 1RM, respectively. The MF slopes (Hz s^{-1}) decreased significantly for CG after the training period in 40% 1RM, with no changes for TG. The MF intercepts (%MVC) for CG in the pre-training were 11.04 ± 11.40; 9.81 ± 9.52; 9.56 ± 9.11; 14.16 ± 12.35, and post-training were 13.96 ± 12.06; 13.54 ± 11.71; 13.38 ± 10.81; 14.16 ± 12.35 for 25%, 30%, 35% and 40% 1RM, respectively. No significant differences were found in RMS and MF intercepts after the training period for both groups.

3.6. Training effects in the multifidus

No significant differences were found in the RMS slopes, while for the MF slopes, significant decreases were observed (except in 30% 1RM, Fig. 6) for TG. No significant differences were found in the RMS intercepts, while for the MF slopes, significant decreases starting from 30% 1RM were observed (Fig. 6).

4. Discussion

The main objective of the present study was to analyze the EMG activity of the elbow flexor muscles after an EMG_{FT}-based training session. The EMG amplitude (RMS) for elbow flexion agonist muscles presented training effects, while the frequency EMG parameters remained unchanged or presented only few alterations. The RMS training responses in isometric contractions for biceps brachii and brachioradialis muscles were different, with decreases on the biceps brachii (Kollmitzer et al., 2000; Marson and Gonçalves, 2003) and increases on the brachioradialis values (McBride et al., 2003; Ozmun et al., 1994). Alterations on the RMS may be related to increases on the motor unit (MU) synchronism, as consequence of motor learning, which reduces the EMG activity (Enoka, 2000). On the other hand, there may be larger neural activation related to a hypertrophic adaptation and a short training period that causes increases on the RMS during maximal contractions (Kraemer and Ratamess, 2004;

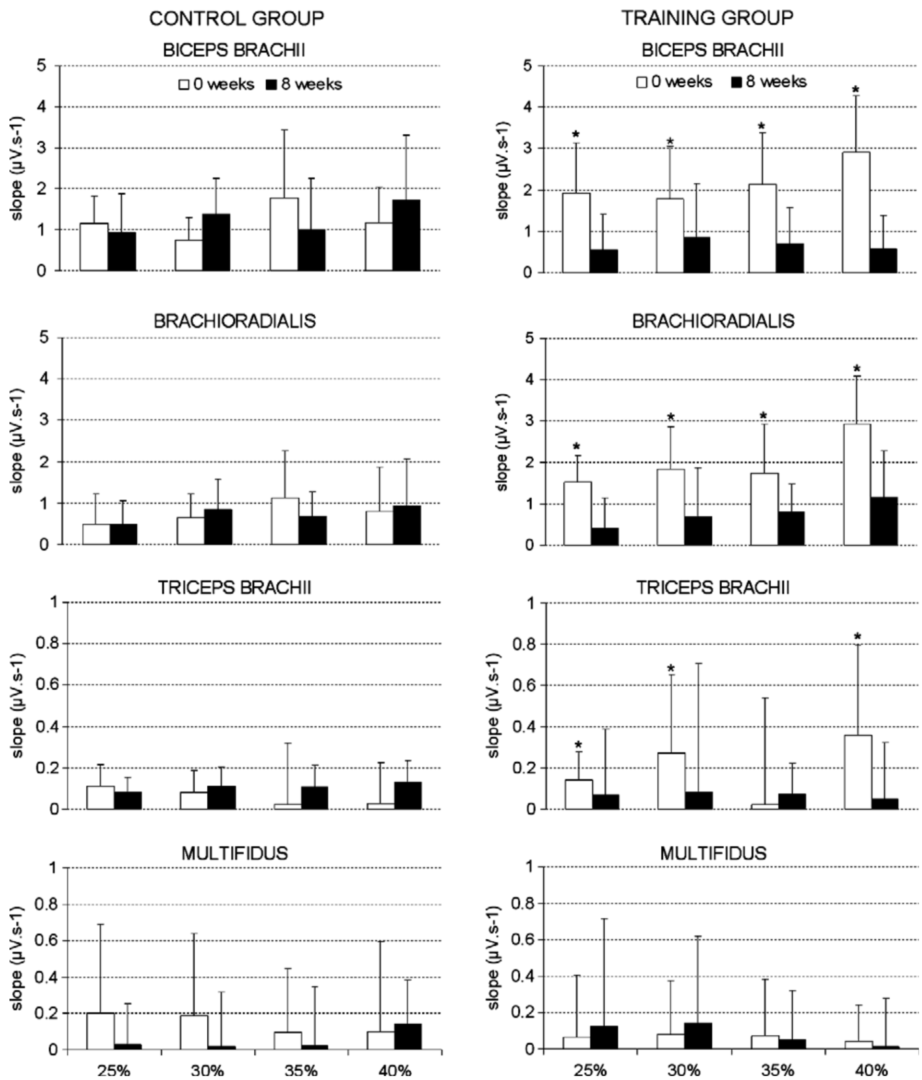

Fig. 5. Biceps brachii, brachioradialis, triceps brachii and multifidus slopes of the root mean square (RMS) for control group and training group before (0 weeks) and after the training (8 weeks). *Significantly different from 8 weeks.

Table 1
Root mean square intercepts (% 1RM) of the biceps brachii (BB), brachioradialis (BR), triceps brachii (TB) and multifidus (TB) muscles at the four load levels (25%, 30%, 35% and 40% 1RM) of the biceps curl exercise to the control group (CG) and training group (TG) before (0 weeks) and after (8 weeks) the training period

	25%		30%		35%		40%	
	0 weeks	8 weeks	0 weeks	8 weeks	0 weeks	8 weeks	0 weeks	8 weeks
CG								
BB	36.63 ± 14.43	42.42 ± 25.13	33.79 ± 10.20	36.58 ± 20.11	38.35 ± 10.34	42.36 ± 21.41	46.13 ± 17.47	42.05 ± 16.71
BR	30.51 ± 15.08	32.50 ± 11.38	36.33 ± 15.82	32.41 ± 10.59	40.42 ± 19.11	36.15 ± 10.65	44.23 ± 16.75	40.54 ± 13.63
TB	5.27 ± 2.73	5.48 ± 3.03	6.03 ± 3.92	6.35 ± 4.48	8.72 ± 7.92	6.79 ± 4.67	7.96 ± 6.34	5.80 ± 4.24
TM	25.98 ± 17.22	21.91 ± 10.30	26.99 ± 19.08	24.24 ± 11.43	30.01 ± 18.69	28.29 ± 16.80	22.61 ± 9.05	28.20 ± 12.29
TG								
BB	23.07 ± 12.04	35.51 ± 14.00	32.56 ± 14.28	38.54 ± 18.12	31.53 ± 14.55	38.61 ± 15.53	39.12 ± 10.40	47.88 ± 26.22
BR	33.05 ± 18.24	28.78 ± 12.66	35.04 ± 19.86	28.19 ± 11.41	39.14 ± 14.09	33.31 ± 9.63	41.76 ± 15.71	40.47 ± 13.04
TB	5.70 ± 3.44	4.97 ± 2.97	5.93 ± 2.99	4.74 ± 3.03	6.34 ± 3.61	5.25 ± 3.11	6.70 ± 3.84	6.23 ± 4.19
TM	24.99 ± 12.64	22.23 ± 10.82	29.41 ± 17.45	24.20 ± 13.71	27.32 ± 12.15	25.4 ± 12.468	32.04 ± 16.58	29.03 ± 15.10

McBride et al., 2003). Notwithstanding, the training characteristic or specificity (dynamic) may result in undesired neuromuscular responses (Campos et al., 2002), as verified in the present study, because the maximal isometric force remained unchanged after training. Previous studies have verified absence of relationship between the increase in

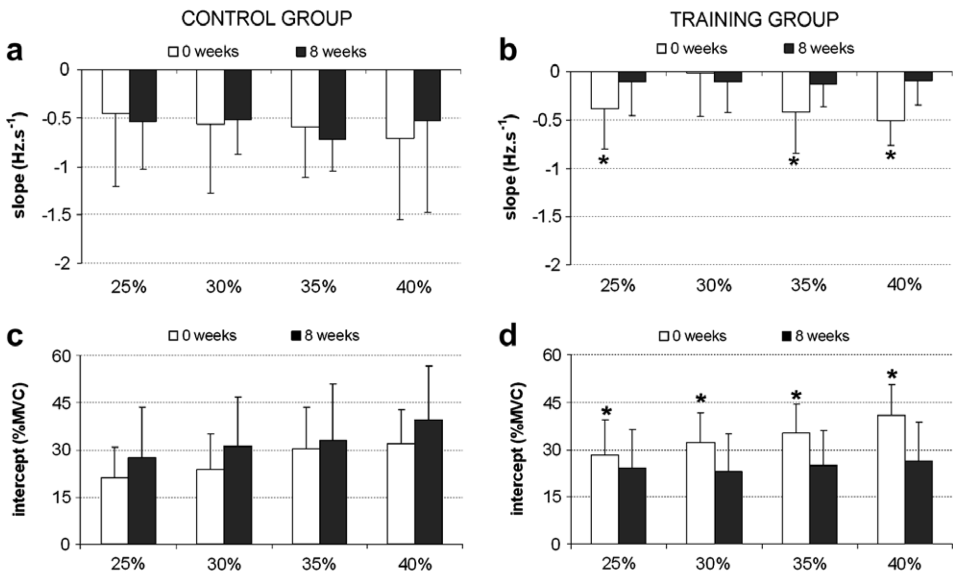

Fig. 6. Multifidus median frequency slopes for control group (a) and training group (b), and median frequency intercepts for control group (c) and training group (d) before (0 weeks) and after the training (8 weeks). *Significantly different from 8 weeks.

the isometric force and EMG activity in resistance training. For agonist muscles, no increases in EMG activity was observed and surprisingly decreases EMG activity were also observed (Holtermamm et al., 2005), as in the present study. In addition, the brachioradialis muscle may reach higher activation than the biceps brachii muscle, and its EMG values may increase after a resistance training (Shield and Zhou, 2004). Previous studies that investigated the muscle function in the elbow flexion presented larger activation of the brachialis muscle, followed by biceps brachii and brachioradialis. However, in the present study, the brachioradialis was more active than the biceps brachii in isometric conditions.

Although no differences have been verified in the EMG_{FT} related to training, a significant increase in the 1RM for the TG was observed, as in previous studies on elbow flexion resistance training (Campos et al., 2002; McBride et al., 2003). In addition, isometric contractions presented no differences in relation to the force output. This fact could be explained by the specificity principle (Campos et al., 2002; Weineck, 1999), since the training program was based on dynamic contractions, and weak relationships between force increase and dynamic or isometric contractions in these conditions were found (Komi, 1992; Weineck, 1999).

Decreases in the slope values presented in this study are related to training and could be explained by increases on the force output (Campos et al., 2002) and motor learning, which cause lower muscle activity levels in a specific load (Weineck, 1999; Lay et al., 2002). Only for multifidus MF, the intercept values presented training-related changes. This variable is defined as the initial recruitment values for a specific muscle in fatiguing tasks (Hummel et al., 2005), and it was used to calculate the EMG_{FT}. In this sense, for elbow flexor and extensor muscles, the decrease in the RMS values over the exercise time course and, considering the intercept values, the initial activation remains unchanged with the training session. Thus, according to previous studies (Barbosa, 2005; Cardozo, 2006), the EMG_{FT} presented no training-related differences., Although the endurance time has also increased (Barbosa, 2005; Cardozo, 2006), it could not be associated with changes on the EMG_{FT}. The EMG amplitude and frequency presented training-related differences. The RMS slopes for biceps brachii and brachioradialis decreased while the MF slopes for these muscles remained unchanged. Decreases in the RMS slopes might be explained by increases in the force output and motor learning, as previously cited (Campos et al., 2002; Lay et al., 2002), while the MF slopes are less affected by these factors, and they might be rather more affected by changes in the metabolites accumulation related to fatigue (De Luca, 1997; Masuda et al., 1999), as well as by the type of muscle fiber (Linnamo et al., 2003; Mercer et al., 2006).

The triceps brachii EMG activity during biceps curl exercise demonstrates that, due to the antagonist function, this muscle also presented adaptations to training sessions as observed by lower slopes. In other words, lower MU recruitment over the time course, as demonstrated by Pousson et al. (1999), which may be justified by the motor learning promoted, reducing the recruitment of unnecessary MU (Osu et al., 2002).

Many studies have been conduced on the multifidus activity in standing position tasks (Moseley et al., 2002; Oliveira et al., 2006; Zedka and Prochaska, 1997). The present study showed no changes in the multifidus RMS after training, while the MF slope increased and intercepts decreased. These adaptations in the trunk muscles related to the EMG_{FT}-based training might reduce the fatigue effects. This fact is important for beginners in resistance training, since these exercises in standing position may cause injuries during a poorly oriented training session (Bompa et al., 2003; Bono, 2004).

It was concluded that the training specificity causes different responses between isometric and dynamic contractions, with training-related effects on the contraction type used for training (dynamic). The training program based on the EMG_{FT} values decreases the elbow flexor and extensor RMS, demonstrating that the amplitude parameters could be more effective to resistance training evaluations, since this parameter presents different regulatory mechanisms, and frequency parameters, and although highly related to fatigue, it remained unchanged. On the other hand, the multifidus muscles was altered with training, demonstrating possible adaptations to fatigue using EMG_{FT}, even without a specific training program for this muscular group.

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