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Is the 10-RM test ideal for evaluating trained and untrained individuals?

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ORIGINAL ARTICLE

ABSTRACT

The objective was to evaluate whether the 10-RM test can be applied to both trained and untrained people in elbow flexor strengthening exercises. The sample consisted of 23 men aged between 18 and 30 years old, of which 11 were untrained (NT - control group), and 12 were resistance-trained (TR - trained group). The experiment started with a specific warm-up session followed by collections of myoelectric signals from the brachial biceps muscle, bilaterally, in Maximum Voluntary Isometric Contractions (MVIC), the 10-RM test for elbow flexion and the new MVIC, followed by deceleration. By analyzing each contraction separately contraction, a significant increase in RMS (Root Mean Square) was found by a normalized MVIC with regard to 1st contraction, starting from the 3rd repetition for the TR group. When comparing each contraction of the 10-RM test with the previous one, a significant reduction of MF (Median Frequency) between the 5th and the 6th repetition of the TR group was observed. It was concluded that the Test of 10 Maximum Repetitions should be reconsidered when performed for purposes of comparison between sides of the body. Also, when considering the probable fatigue caused by the successive movements, a better application of tests with 6 to 8 repetitions was suggested.

Keywords: Exercise, Resistance Training, Muscle Weakness, Exercise Test

INTRODUCTION

Muscle fatigue can be described as the transient decrease induced by exercise in the force or at the maximum power that the muscle is capable of producing. The process is gradually established a few moments after the start of sustained activity and can be caused by different mechanisms, such as the accumulation of metabolites within the muscle fibers, the inadequate generation of motor control from the motor cortex, among others (Enoka & Duchateau, 2008).

Several study designs have been used to study muscle fatigue through electromyography in dynamic actions with submaximal loads. Maximum isometric contractions can be interspersed between several sessions of submaximal contractions (Rogers & MacIsaac, 2013; Bandpei et al., 2014).

However, it is known that periodic and continuous training produces significant physiological and morphological changes in the behavior of the neuro-musculoskeletal system, which is also true in the case of resistance training, in which there is an increase in strength, power, or muscular endurance, hypertrophy and improved agility, motor coordination and / or flexibility, for example (Nicholas et al., 2009). In addition, increased strength production and muscular hypertrophy are also related to increased amplitude of the electromyographic signal in maximal actions (Oliveira & Gonçalves, 2009). Factors such as men vs. women, trained vs. untrained, young vs. adult should be viewed with caution and may

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interfere in the Maximum Repetition (MR) test (Pereira & Gomes, 2003).

Considering the relevance of investigating the repetition maximum tests, the following problem was raised: is there a difference in the electromyographic response of trained individuals and sedentary individuals in the 10-RM test (10 repetition maximum test) due to the fatigue process? In addition, we sought to assess whether dominance significantly influences the electromyographic response. The hypothesis was that there is a difference in the electromyographic response of trained and untrained people as a result of alterations provided by resistance training and that dominance also contributes to or accentuates some differences, especially in untrained persons. Therefore, the objective was to evaluate whether the 10-RM test can be applied to both trained and untrained persons in elbow flexor strengthening exercise.

METHOD

This study was experimental, controlled, analytical, and cross-sectional.

Participants

This study was approved by the Human Research Ethics Committee of the Universidade Federal do Triângulo Mineiro under protocol number 2062/2011. It used a convenience sample, and participants were invited through posters posted in different academies of the city of Uberaba-MG and at the sponsoring institution's dependencies, with the consent of those responsible. The sample consisted of 23 men aged between 18 and 30 years old, of which 11 were untrained (control group), and 12 received resistance training (trained group). Although the sample was not chosen based on a sample calculation, nine individuals were included in each group, according to articles published in journals of recognized scientific merit in Physical Education, recognizing the limitations and difficulties of working with Research on human beings (Ahtiainen & Häkkinen, 2009; Callewart et al., 2013; Gaffey et al., 2012; Julienne, Gauthier, & Davenne, 2012; Uzun et al., 2012).

For the trained group, bodybuilders were invited, as well as people who had been practicing upper-limb resistance exercises for more than one year, more than twice a week. The untrained group was made up of people who had not practiced resistance exercises or bodybuilding in the last six months prior to participating in the research or for more than six consecutive months in the last two years.

Procedures

The research happened in two moments. In the first evaluation, the participants consented to participate voluntarily and answered a questionnaire regarding general personal data, personal and family history of morbidities, history of physical activity practice with details of the period, duration, and description of the systematization of the training performed, when necessary. They were submitted to a physical evaluation involving the evaluation of vital signs, anthropometric measurements of total body mass, stature, skinfolds, and a 10-RM test to determine the strength and localized muscular resistance for the elbow flexion movement, in order to familiarize the participant with the procedures. The second evaluation, performed from 5 to 7 days after the first one, started with a specific warm-up, followed by collections of myoelectric signals from the brachial biceps muscle, bilaterally, in Maximum Voluntary Isometric Contraction (MVIC), the 10-RM test for elbow flexion and the new MVIC, followed by deceleration. Collections were organized so that half of the group started the tests on the dominant side and the other half on the non-dominant side.

Before the maximum effort tests, the volunteers were instructed verbally and visually about the correct way to execute. During the tests, the researcher provided intense verbal reinforcement and encouragement, always using the same standardized phrases, which were elaborated prior to the start of the study. In addition, all collections were performed by the same researcher. Participants were instructed not to consume stimulating foods or beverages on evaluation days, having a good night's sleep, and not engaging in vigorous exercise the day before the assessments.

For the electromyographic analysis, all the standards recommended by the International Society of Electrophysiology and Kinesiology were followed (Merletti & Torino, 1999). The biceps brachii muscles were analyzed bilaterally. The electrodes were placed at two-thirds of the distance between the medial acromion and the cubital fossa, three centimeters distant center-to-center. The reference electrode was placed in the right lateral malleolus to avoid cable movement during dynamic tests and to guarantee a better signal-to-noise ratio during preliminary tests.

Electromyographic Analysis

The four-channel Miotool 400 USB (Miotec®) equipment was used, differential active sensors with gain of 200x per channel, 14-bit A/D converter, a sampling frequency of 2000 Hz per channel, CMRR of 110 dB, noise level <2 LSB (Low Significant Bit) and an input impedance of 1010 Ohm/2pF, with Ag/AgCl electrodes in the shape of a disc with 0.01 m of diameter (MAXICOR®). The signal was analyzed using miography software (Miotec®) and filtered through a 4th order Butterworth bandpass filter (20-500 Hz). Fixed windows at 0.75 seconds from the mean portion of the electromyographic signal were extracted for analysis in isometry and concentric action. The RMS (Root Mean Square) parameters normalized by the MIVM and Median Frequency (MF) using Fast Fourier Transformations were analyzed.

10 Repetitions Max Motor Test

The 10-RM test for elbow flexion was performed through the Concentrated Thread movement with free weights, as described in the literature (Evans, 2007). The participant stayed seated, legs apart, supporting the distal and posterior portion of the arm undergoing the exercise on the inner face of the homolateral thigh, shoulder vertically aligned, elbow, and forearm in supination. The participant should then draw the dumbbell toward the shoulder. It was standardized to perform a fluid movement, following the beat of a metronome at 60 beats per minute (bpm), with one cycle of movement every three beats, that is, focusing one second for concentric action and two seconds for the eccentric movement.

A general warm-up was carried out for five minutes in a cycle ergometer, followed by specific heating consisting of three sets of 10 repetitions with increasing loads of 30%, 50%, and 75% of the estimated load for the realization of the 10-RM, respectively. After the warm-up, a maximum of five attempts was made to identify the 10-RM load with increasing overloads with 3 to 5-minute interval between each attempt, as described in the literature (Brown & Weir, 2001).

During the test, the 10-RM load was considered when the participant was able to perform ten fluid movements without the occurrence of compensations observable by the examiner, at speed compatible with the metronome frequency.

Calibrated dumbbells of one, two, and five kilograms with an accuracy of up to 0.5 kg were used as a result of the difference in actual dumbbell mass. The calibration was performed on a commercial mechanical scale with an accuracy of 0.05 kg. Each dumbbell and bar with staples were measured four times, being considered the mode between the four attempts or the arithmetic mean when presenting two readings with one value and two readings with another value.

Statistical analysis

The sample was divided into 4 subgroups: untrained dominant (NTDO); untrained non-dominant (NTND); trained dominant (TRDO) and; trained non-dominant (TRND). Due to the size of the sample and the majority of non-normal variables, we used the Kruskal-Wallis ANOVA tests followed by the Mann-Whitney U test to analyze the inter-group differences and the Friedman ANOVA and/or Wilcoxon Matched Pairs Test to analyze intra-group differences using Statistica 8.0 software. Data normality was verified with the Kolmogorov-Smirnov test. Effect-size r was computed to every paired group difference using means and standard deviations, Spearman rank correlation (ρ) was applied to verify the reproducibility between the pre-test values obtained during the first day of evaluation and the actual test values obtained on the second day of evaluation for the 10-RM loads. A significance level of less than 5% was used.

RESULTS

Spearman's Correlation coefficient was applied between the preliminary and experimental 10-RM tests. These tests showed a correlation higher than 0.83 for all subgroups.

Table 1
Mean values and statistical correlation between the values obtained in the preliminary and main tests for maximum grip dynamometry and the 10-RM test applied to the brachial biceps muscle.

	Peak force dynamometry (kgf)			10 MR (kg)		
	Pre-test	Main test	*p*	Pre-test	Main Test	*p*
NTDO	44	40.9	.07	8.6	8.72	.83*
NTND	38	35.3	.07	7.9	8.66	.97*
TRDO	52	67.1	.55	14.39	15.25	.98*
TRND	50	54.5	.20	14.79	14.98	.84*

MR = maximum repetitions; NTDO = untrained dominant; NTND = untrained non-dominant; TRDO = trained dominant; TRND = trained non-dominant; ρ = Spearman's rank correlation. * = p<0,05

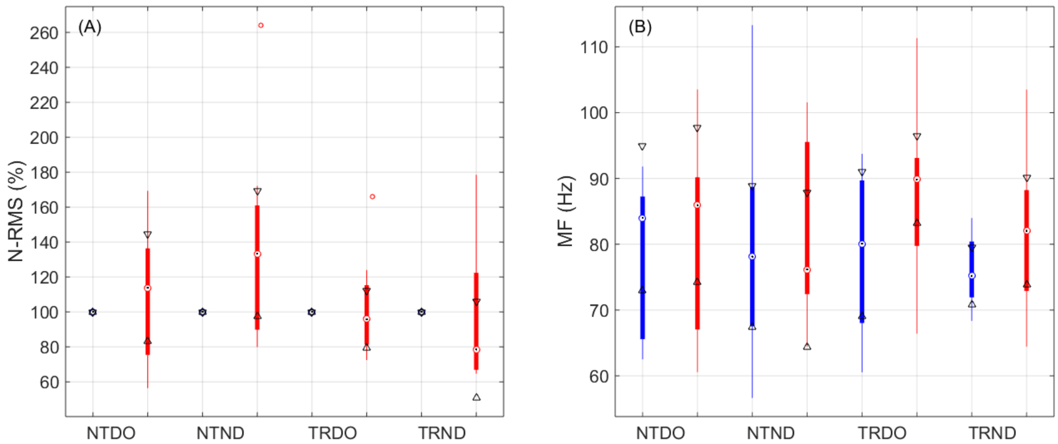

Figure 1. Static electromyographic evaluation in isometry (RMS - Root Mean Square). NTDO = untrained dominant; NTND = untrained non-dominant; TRDO = trained dominant; TRND = trained non-dominant

Throughout the 10-RM test, differences between the TR and NT groups were found only in MF during the 5th and 7th repetitions of the DO member (p = 0.033169; *r* = 0,28 and p = 0.03667; *r* = 0.36respectively).

By analyzing each contraction separately, a significant increase in the RMS was found ,using a normalized MVIC, with regard to the 1st contraction, starting from the 3rd repetition for the TR group (DO and ND) and for the NTND, whereas the NTDO presented a significant increase from the 2nd contraction (Figure 2). In addition, Figure 3 shows a significant reduction in MF with regard to the 1st contraction, starting from the 7th contraction in the NT (DO = p = 0.011719 / 0.017961 / 0.035693; *r* = 0.31 / 0.40 / 0.40), ND (p = 0.017961 / 0.035693 / 0.011719 / 0.017961; *r* = 0.51 / 0.47 / 0.59 / 0.64) and in the TRND (p = 0.032970 / 0.007686 / 0.017961 / 0.007686; *r* = 0.52 / 0.69 / 0.65 / 0.74) groups, whereas in the TRDO group there was a reduction from the 6th repetition on (p = 0.035693 / 0.035693 / 0.011719 / 0.010863 / 0.011719; *r* = 0.38 / 0.36 / 0.47 / 0.44 / 0.55).

When comparing each contraction of the 10-RM test with its predecessor, a significant reduction of MF between the 5th and the 6th repetition of the TRDO (p = 0.015157; *r* = 0.25) was observed. The normalized RMS by the MIVC increased from the 1st to the 4th repetition and again between the 5th and the 6th repetition for the NTDO (p = 0.011719 / 0.011719 / 0.035693 / 0.049951; *r* = 0.08 / 0.07 / 0.10

/0.12) and between the 2nd and the 3rd repetitions of the NTND group (p = 0.035693; *r* = 0.13), while in the TR group it increased between the 2nd and 3rd repetitions side of the DO side (p = 0.015157, *r* = 0.15) and between the 4th and 5th repetitions side of the ND side (p = 0.007686; *r* = 0. 06).

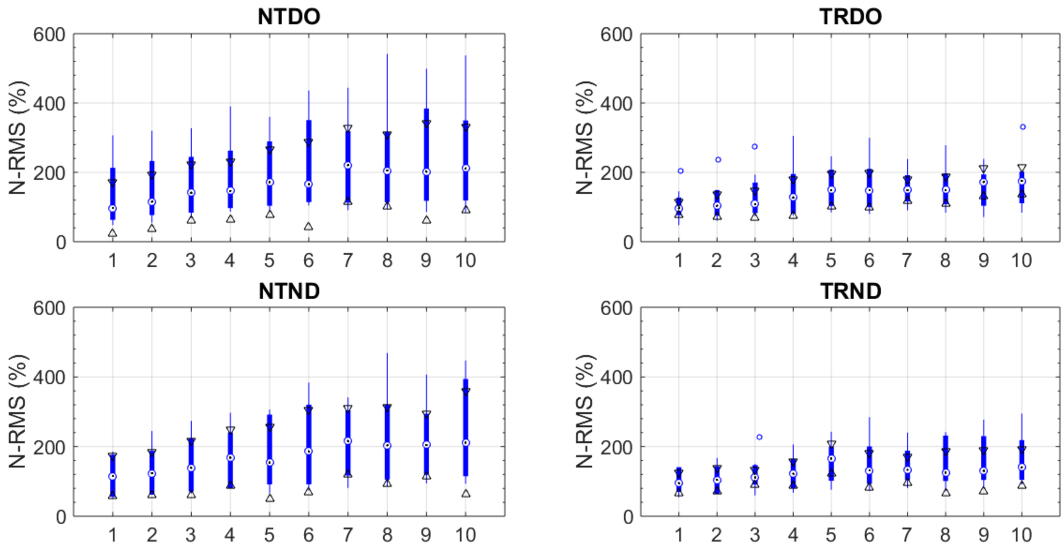

Figure 2. Analysis of RMS (Root Mean Square) contraction by contraction. NTDO = untrained dominant; NTND = untrained non-dominant; TRDO = trained dominant; TRND = trained non-dominant

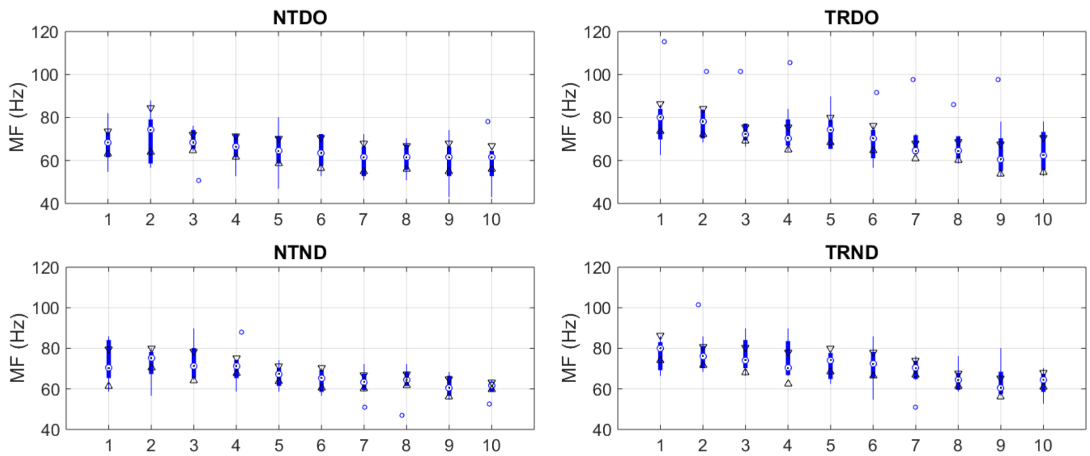

Figure 3. MF (Median Frequency) analysis. NTDO = untrained dominant; NTND = untrained non-dominant; TRDO = trained dominant; TRND = trained non-dominant

DISCUSSION

The present study sought to investigate the process of muscle fatigue during and after the 10-RM test for the brachial biceps muscle through EMG and palmar grip dynamometry in untrained and resisted exercise for more than one year. No study comparing electromyographic variables between each repetition during the 10-RM test for upper limbs was found, taking into account the dominance and influence of resistance training.

Comparisons between trained and untrained individuals or between dominant and non-dominant limbs using electromyography were found only in multiple series of 8-12 RMs (Ahtiainen & Häkkinen, 2009; Izquierdo et al., 2011; Walker et al., 2012). Surface electromyography has a promising effect for the analysis of electrical signal capture of the muscles, without being invasive, and can monitor, in real-time, its fatigue and at what time it begins (Correa-Figueroa et al., 2016).

A previous study analyzed lower limb muscles from surface electromyography in movements resisted until exhaustion (Croce et al., 2016) and verified changes in the frequency and decrease of signal amplitude as indicative of muscle fatigue (mean torque decreased 75.6%).

Our study sought to include young adults among whom the physiological variables did not differ between groups. However, anthropometric variables presented higher values for the group of trained individuals, especially for body mass, which is coherent when dealing with these volunteers' profiles and the changes resulting from resistance training. It is in agreement with the literature (Abad et al., 2010; Veloso et al., 2010).

The 10-RM test was able to identify muscle fatigue, as observed by concentric mechanic failures in the 11th repetition. In addition, there was a significant reduction of MF in the electromyographic evaluation in the last repetitions for all groups (Figure 3). It was observed that trained people could move higher loads and sustain the same initial mechanical performance over untrained ones, even with signs of early-onset muscle fatigue, especially for the DO subgroup. On the other hand, the NT group should show a greater increase in the recruitment of new motor units before the TR group, especially for the ND group, observed by the early increase in the amplitude of the electromyographic signal in relation to other subgroups. Another study compared the performance of six different algorithms to detect and quantify muscular fatigue based on electromyographic signals. Although they claim that few individuals were analyzed, the results indicated no single best algorithm for fatigue detection, but they indicate a slight tendency for spectral momentum reasoning to evaluate fatigue (Kahl & Hofmann, 2016).

During the isometric electromyographic evaluation, only the TR-DO group presented a reduction of MF at the end of the 10-RM test, without any alteration in the other subgroups. No significant changes were observed in the normalized RMS. Differing trends between NT and TR were observed in the normalized RMS, and values after the 10-RM test tended to increase for NT and decrease for TR on both sides. Another study (Ahtiainen & Häkkinen, 2009) did not observe any electromyographic change when evaluating the integral signal after a series of uniaxial exercises for knee extension in athletes and nonathletes, although with a reduction of force production, suggesting that the fatigue had peripheral origin without any central impairment. It is noteworthy that, in the present study, the isometric test occurred immediately after the completion of the 10-RM test. Therefore it is not believed that significant recovery could occur between the last 10-RM test and isometry.

During the 10-RM test, when comparing the other contractions with the first one, three of the subgroups presented a reduction of MF from the 7th repetition, except for the TRDO subgroup that started on the 6th. This subgroup was also the only one to present a significant reduction in the 6th repetition in relation to its predecessor, indicating a more pronounced MF reduction in this transition. In the 5th and 7th repetitions, significant differences were also found between the NTDO and TRDO subgroups, with the lowest values for the NT group. Apparently, FM values started higher for the TR group and presented a more significant reduction matching the NT group values at the end of the 10th repetition, although these differences were not significant. A study carried out in a slightly different population, and with other tools and others researchers (Latasa et al., 2016) evaluated new changes in spectral indicators after exercises on a cycle ergometer in 14 cyclists, using the variable average frequency and MF, based on an electromyographic analysis of the vastus lateralis muscle. However, they failed to indicate a starting point for muscle fatigue during the test, based on the presented methodology, obtaining opposite effects in half of the group of evaluated individuals.

MF is used to quantify changes in the spectral content of the EMG signal based on the Fourier Transform and is related to changes in the speed of the conduction of the fibers and consequent changes in the wave duration of the action potential of the motor units. Although their behavior is controversial, in dynamic contractions, it has been shown that FM usually decreases during fatiguing activities (Gonzáles-Izal et al., 2012). In addition, it has great validity in the study of muscle fatigue due to the number of articles published, as previously described. Thus, TRDO was the first to show signs of muscle fatigue but was able to maintain the displacement of the largest load until the last repetition. This could be indicative that trained people can withstand working under electromyographic fatigue conditions for longer.

Findings from the other study (Jenkins et al., 2015) suggest that there may be specific adaptations of the fiber type, and they are directly linked to the type of load used during exercise. Exercises with 80% of 1-RM may result in greater hypertrophy of type II fibers, whereas training with 30% of 1-RM may result in greater hypertrophy of type I fibers, which could also explain the findings of the present study since trained individuals would have a high percentage of fast fibers compared to untrained ones.

Studies evaluating neuromuscular activity during high-intensity exercises suggest that these changes in the frequency spectrum of the muscles involved would possibly indicate selective fatigue of fast-twitch fibers. This selective fatigue may be related to increased fatigue in individuals with a high percentage of fast fibers, which could also explain the findings of the present study since trained individuals would present a high percentage of fast fibers when as compared to untrained fibers (Billaut et al., 2006; Bogdanis, 2012; Kupa et al., 1995).

Findings reported by another study (Jenkins et al., 2015) suggest specific adaptations of each type of fiber, directly linked to the type of load used during the exercise. Exercises with 80% of 1 MRI resulted in greater type II fiber hypertrophy, whereas 30% of 1 MRI training resulted in greater hypertrophy of type I fibers, which could also explain the findings of the present study since trained individuals presented a high percentage of fast fibers compared to untrained ones. Another study compared the time before a failure of the electromyographic signal during sustained maximum and submaximal tasks for the brachial biceps muscle of 18 individuals. The results emphasized the task-dependent nature of neuromuscular fatigue, that is, there were intensity-dependent neuromuscular adjustments, which led to the differences found for the time of failure (electromyographic signal decline) (Carr et al., 2016).

The normalized RMS progressively increased from the 3rd repetition to the three subgroups in relation to the 1st contraction, with the exception of the NTDO that started already from the 2nd repetition. For three of the subgroups, the increase was higher from the 3rd repetition, with the exception of the TRND, among whom it took place starting from the 5th repetition. The increase in the amplitude of the electromyographic signal is mainly related to the increase in the rate with which signals were triggered, to the recruitment of a larger number of motor units and a greater synchronism between them, as well as to the shape and velocity of propagation of the potential for action (Gonzáles-Izal et al., 2012 Stock et al., 2012; Sundstrup et al., 2012). Although no significant difference was found between the TR and NT groups, the NT group's premature recruitment could demonstrate greater unpreparedness to maintain a certain overload than the TR group, needing to recruit more motor units from the initial repetitions.

There was also an apparent tendency for the amplitude values of the TR group's signals to be similar to the values for the NT group in the first repetitions. The difference between them increases in the last repetitions due to a more expressive increase for the NT group, especially in RMS values normalized by the MVIC. The electromyographic activity of trained persons is known to be superior in maximum activities due to the greater capacity to recruit motor units synchronously, thus generating greater tension in a given instant. Others authors analyzed this process and argued that this might suggest a reduction in neural drive and muscle activation due to the fatigue process (Bogdanis, 2012; Mendez-Villanueva et al., 2008) and that the parallel decrease in electromyographic activity and power in one sequence of sprints may be a consequence and not the cause of the reduction in performance. These inferences also corroborate observations about the reduction of FM in TR individuals.

In the present study, we chose to use the MVIC in 90° elbow flexions to normalize both isometric and dynamic contractions. A previous study (Burden, 2010) found no strong evidence of the need to use other standardization methods to compare successive contractions. The possibility of performing a maximum dynamic contraction with the same evaluated activity parameters would place an even greater overload on the evaluated muscle and could influence the results found.

Although performed under qualified professional supervision, performing tests with standardized movements on equipment capable of restricting movement and limiting compensation could be employed to isolate further the muscle activity desired.

CONCLUSION

It is concluded that the 10 Repetition Maximum Test is influenced by a different underlying physiological process resulting from muscle adaptations to increased overload and dominance. The electromyographic analysis revealed different behaviors from both trained and untrained individuals, as well as from dominant and non-dominant sides. Earlier reductions in MF were found for trained and dominant subgroups. On the contrary, muscle activation was more prominent for untrained and non-dominant subgroups. Although providing valuable information for resistance training practitioners and professionals, tested muscles are undergoing different processes and, therefore, other RM tests should be assessed for better comparisons.

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Conflict of interests:
Nothing to declare.

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