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RESISTANCE EXERCISE TRAINING: COMPARATIVE ANALYSIS OF MORPHOLOGICAL ADAPTATIONS AND CAPACITY TO GENERATE FORCE BETWEEN TENSIONAL AND METABOLIC METHODS

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ABSTRACT

The objective was to compare the morphological adaptations and the capacity to generate force promoted by the tensional versus metabolic resistance exercise. The sample consisted of 28 men, between 18 and 45 years old, resistance exercise practitioners divided into two groups. Anthropometric evaluation and maximal strength test were performed before and at the end of the training period. The hypertrophic responses were intensified by the metabolic method and the ability to generate force by the tension-base method. Thus, it is concluded that the morphological adaptations and the capacity to generate force are dependent on the application and control characteristics of the load, in other works, the applied method.

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INTRODUCTION

Resistance training or resistance exercise or strength training covers a wide range of different training forms (Fleck and Kraemer, 2017) aimed at promoting adaptations focused on muscle enhancement, mainly the ability to develop strength and increase tissue density (hypertrophy) (Fahey, 2014). These adaptations are considered successful when there is the correct use of sports training principles (Prestes, Foschini *et al.,* 2016), the appropriate balance among volume, and interval control, as well as the application of adequate execution speed for the intended purpose (Fleck and Kraemer, 2017). In the specific literature there is a terminological diversity for resistance training or resistance exercise methods, the most common being the denominations based on the load used or the specific modalities (weightlifters, bodybuilders), causing a general inaccuracy between the method nomenclature, the intended objective and the result achieved. To facilitate the understanding of resistance training, didactically can be divided into two manifestations, tensional resistance training and metabolic resistance training (Gentil, 2014), whose variations in load or overload enable stimuli to different forms of force manifestations (Allegretti, Charro *et al.,* 2018). The tensional resistance training is characterized by mechanical stress imposed to the muscle tissue, which may, or may not, be able to change the local metabolism and to increase the expected stimuli by means of a smaller number of repetitions and by higher loads (close to 1RM) due to the prevalence of the allelic anaerobic metabolism. The hypertrophic hypothesis of this method lies on the possible micro lefts, which result from the eccentric phases of the movement, mainly in the Z lines, and on sarcolemma (Gentil, 2014; Allegretti, Charro *et al.,* 2018). The metabolic resistance training is characterized by a larger group of repetitions (15 or more repetitions) (Gentil, 2014), lower loads and shorter intervals between stimuli (Allegretti, Charro *et al.,* 2018). This method keeps the muscle active in pre-occlusion state for longer than the tensional method, which moves the prevalent energy input to the lactic anaerobic system (Sobral and Rocha, 2017). Based on scientific recommendations by the American College of Sports Medicine (ACSM), the most appropriate method to get to the best hypertrophic responses must encompass higher loads (approximately 80% of 1RM) and 8 to 12 repetitions

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(Ratamess, Alvar *et al.,* 2009; Fahey, 2014; Fleck and Kraemer, 2017). However, investigations involving different populations, namely, sedentary and trained women, sedentary and trained men, among others, subjected to different training times (from 4 to 12 weeks), as well as a wide variety of muscle groups suggested by ACSM, didn't find positive results for hypertrophy responses, although this method is recommended for this purpose (Azevedo, Demampra *et al.,* 2007; Wilborn, Taylor *et al.,* 2009; Polito, Cyrino *et al.,* 2010; Custódio, Mir *et al.,* 2011; Neves, Neto *et al.,* 2014). On the other hand, researchers such as Mitchell, Churchward-Venne *et al*. (2012) and Fry, Glynn *et al*. (2010) suggest that the stimuli from low loads (30% to 40% of 1RM) under suitable conditions are efficient to reach good hypertrophic responses. Investigations involving these suggestions, control and intervening variables have shown positive hypertrophic responses in samples subjected to resistance training (Fry, Drummond *et al.,* 2011; Takada, Okita *et al.,* 2012). Accordingly, despite the different recommendations about loads, number of repetitions and recovery intervals, resistance training methods can be used when hypertrophy is a common focus (Prestes, Foschini *et al.,* 2016). Thus, the objectives of the present study were to compare the morphological adaptations and the capacity to generate force promoted by the tensional versus metabolic resistance exercise.

MATERIALS AND METHODS

The study was submitted to, and approved by, the Ethics Committee on Research with Human Beings of State University of West Paraná, on July 27, 2018 – opinion number 2.787.781. The sample comprised 28 men in the age group 18-45 years who had volunteered to participate in the experiment and who met the following inclusion criteria: to be in the chosen age group, time practicing the resistance training (for at least 3 months and for no longer than 3 years); don't present lesions, heart diseases or diabetes, and not to be using dietary or anabolic supplements. The sample for the resistance training programs was divided into two groups: Experimental Group A (EGA) and Experimental Group B (EGB). Each group encompassed 14 subjects who were randomly distributed through simple drawing - all procedures were performed before the Free and Informed Consent Term was signed (FICT). Training protocol (volume and intensity): EGA exercised with maximum load of approximately 80% of 1RM set on 3 series with 8 to 12 repetitions, according to recommendations by ACSM (Ratamess, Alvar *et al.,* 2009). The interval of repetitions determined by the protocol was followed when it was not possible to increase or reduce the load (Ratamess, Alvar *et al.,* 2009; Fleck and Kraemer, 2017). EGB exercised with maximum load of 60% of 1RM, set on 4 series with 16 repetitions by taking into consideration the minimum loads needed to generate hypertrophy, according to Uchida, Charro *et al*. (2013). Load adjustment was determined based on the presence of concentric failure before the 16 repetitions. The same time interval between series and between exercises was applied to both groups, namely: 60 seconds between series and 180-240 seconds between exercises. Both groups performed the following exercises: bench press, low rowing, elbow flexion, elbow extension, leg extension and bending legs. Repetition duration (cadence) was 4 seconds, i.e., the concentric and eccentric phase of the isotonic contraction was expected to happen within 4 seconds. Maximum Load Test (1RM) was based on the protocol by Brown and Weir (2001) which encompasses 1) General heat (3 to 5 minutes), 2) slight and brief stretches, 3) test acclimation phase with 8 repetitions and 50% of the estimated maximum load at 3-minute intervals; 4) 3 repetitions and 70% of the estimated load and 5) load increase until the practitioner makes a single complete isotonic contraction at time interval of 5 minutes after each load increment; the test was concluded when the participant was not able to reach the maximum load until the fifth-load increment. If necessary, a new test should be performed 48 hours later. Anthropometric evaluation: the protocol and the equations suggested by De Rose (1984) were used to evaluate the body composition. Fat percentage (%F) was determined through the Faulkner formula (%F = (Σ of the 4 folds x 0.15) + 5.78) - fatty weight (FW) was expressed as kilograms (FW = TW * (%F/100)). The Von Döble method adapted by Rock was used to calculate bone weight (BW), this method uses stature data, radius diameter (bisthiloid) and femur diameter (biepicondilian) ($BW= 3.02*(S^2*R*F*400)^{0.712}$; wherein, S^2 = squared stature expressed in meters, R = radius diameter (bisthiloid) expressed in meters and F = femur diameter (biepicondylian) expressed in meters. The formula proposed by Würch (RW = TW * (24.1/100)) was used to determine the residual weight (RW), since this protocol rationalizes muscle weight (MW) based on Drinkwater. Muscle weight (MW) was calculated by subtracting the total weight (TW) of the simple sum of FW, BW and RW (MW = TW - (RW + BW + FW)). Total weight (TW) was determined by simply weighing the subject on a regular scale and by measuring stature with a stadiometer coupled to the scale. Limb perimetry (circumference) was determined based on the protocol described by Rocha (2016). Results were expressed as mean and standard deviation of the mean. We use the Student's t-test for independent samples and unpaired data. ANOVA TWO-WAY with Tukey's post-test, were used in the comparative analysis of results before and after the training period. Data analysis and plotting were performed in the Graph Pad Prism System software (San Diego, CA, U.S.A.). Differences were statistically significant when $p \leq 0.05$ (*) and $p \leq 0.01$ (**).

RESULTS

Based on the results, morphological adaptations and capacity of generate force was depend on the adopted resistance exercise method. The mean age of subjects in EGA were 21.42±0.99 years and that of the ones in EGB was 24.14±1.53 years. The statistical analysis indicated no difference in participants' mean age between the two experimental groups. Subjects in EGA had been practicing the resistance training for 12.28±1.50 months, on average, and the ones in EGB had been doing so for 13.00±1.77 months, on average. Moreover, it has indicated no difference in mean time of practice between the two groups. Regardless of the sample analyzed or the anthropometric variable, the sample groups showed no statistical difference when comparing the results before and after the training period (Figure 1A, 1B and 1C). Anthropometric circumference data corroborated the previous variables, showed no statistical difference, suggesting that there aren't significative changes in the anthropometric variables, except for the thorax in EGB, that performed metabolic resistance exercise (Table 1). The capacity to generate force before and after the training period increased in four out of six variables in the EGA ($p \leq 0.01$), but in the EGB, except in leg extension ($p \leq 0,05$), all other variables showed no statistical difference (Table 2).

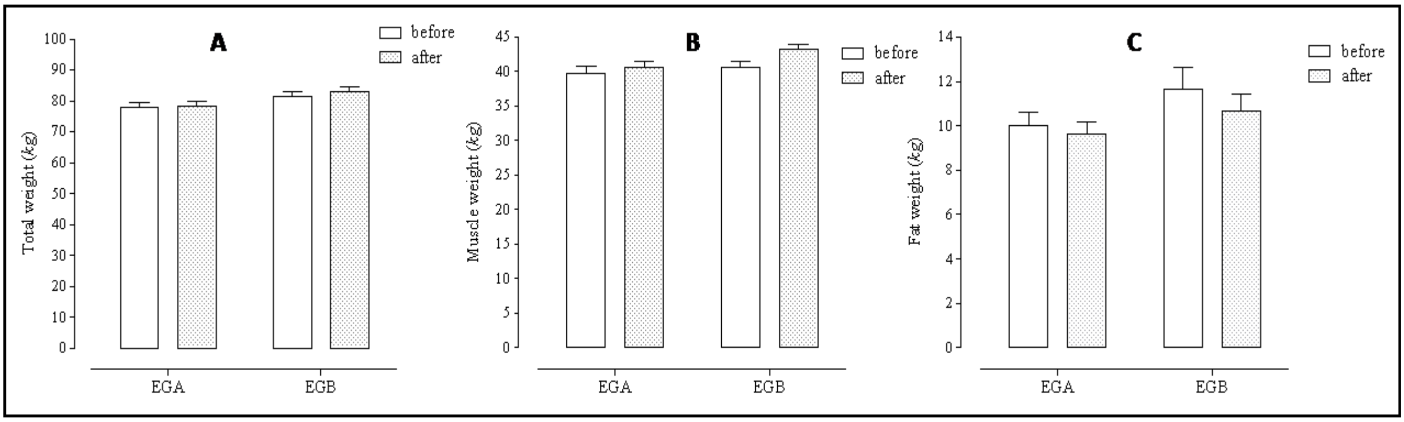

Figure 1. Anthropometric data of the samples before and after the training period. A - Total weight; B - Muscle weight; C - Fat weight. Data were organized as mean and standard deviation of the mean. The test ANOVA two-way with Tukey's post-test, indicates no statistical difference. Source: author´s data

Table 1. Quantitative data about the circumference of the evaluated limbs before and after the resistance training program

	EGA		EGB	
	Before	*After*	*Before*	*After*
Arm	30.23 ± 0.34	31.84 ± 0.35	31.68 ± 0.61	33.80 ± 0.49
Thorax	95.09 ± 0.73	97.68 ± 0.80	96.65 ± 0.92	100.09 ± 0.74**
Leg	54.36 ± 0.69	55.50 ± 0.63	51.50 ± 0.74	53.75 ± 0.75

Data were organized as mean and standard deviation of the mean. EGA group subjected to tensional resistance training. EGB group subjected to metabolic resistance training. Statistically different in the ANOVA two-way with Tukey's post-test, with significance level of p≤0,01 (**). Source: authors' data.

Table 2. Quantitative data about the 1 RM test, before and after the resistance training program

	EGA		EGB	
	Before	*After*	*Before*	*After*
Bench press	29.50 ± 2.17	39.83 ± 2.56	32.28 ± 2.21	36.85 ± 2.54
Low rowing	73.00 ± 2.99	91.33 ± 3.80**	79.00 ± 2.93	93.14 ± 5.14
Elbow flexion	64.00 ± 2.81	77.00 ± 2.93	67.14 ± 3.22	75.57 ± 4.37
Elbow extension	62.50 ± 3.17	80.00 ± 3.58**	66.85 ± 3.26	80.00 ± 5.12
Leg extension	84.83 ± 1.95	111.00 ± 4.27**	99.71 ± 3.27	115.28 ± 4.38*
Bending legs	68.00 ± 2.30	90.00 ± 4.36**	66.28 ± 3.07	80.57 ± 4.01

Data were organized as mean and standard deviation of the mean. EGA group subjected to tensional resistance training. EGB group subjected to metabolic resistance training. Statistically different in the ANOVA two-way with Tukey's post-test, with significance level of p≤0,05 (*) and p≤0,01 (**). Source: authors' data.

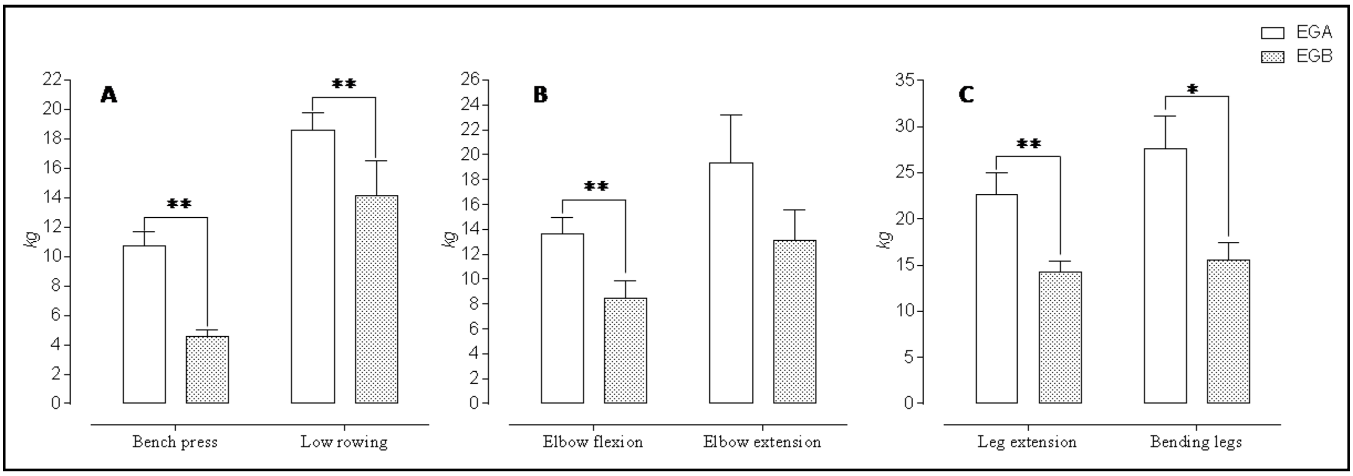

Figure 2. Strength gain, in the maximum load tests, after the training period between EGA *vs* EGB. A - Comparison between thorax strength gain; B - Comparison between arm strength gain; C - Comparison between leg strength gain. Data were organized as mean and standard deviation of the mean. Statistically different in the *student t* test applied to unpaired samples, for non- parametric data were determined through the Shapiro-Wilk protocol, with significance level of p≤0,05 (*) and p≤0,01 (**)

These data suggest that tension-base resistance exercise is more efficient in improving the capacity to generate force. The strength gain comparison between experimental groups showed that the tensional method is more efficient than the metabolic method to increase the strength capacity.

Based on the results, there was statistical difference after the performance of all exercises, except for bench press and elbow flexion (Figure 2). It is possible stating that the metabolic method is more efficient in hypertrophic development. Figure 3 indicates significant increase in arm and leg circumference

(Figure 3A), as well as muscle weight gain (Figure 3B). Although there was not statistical difference in thorax circumference (Figure 3A), total weight and body weight results recorded for the metabolic method were the best ones (Figure 3B).

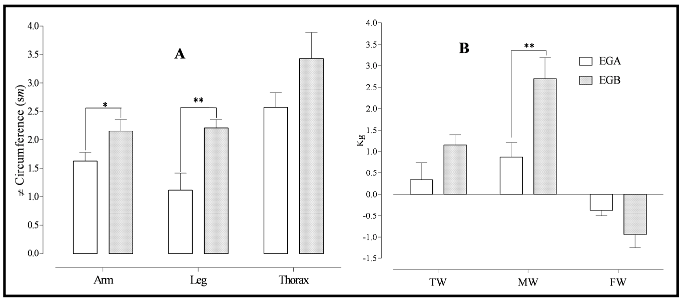

Figure 3. Anthropometric data after the training period. A - Comparison between differences/gain in circumference. B - Comparison of Total Weight (TW), Muscle Weight (MW) and Fat Weight (FW) differences/gain between EGA and EGB. Data were organized as mean and standard deviation of the mean. Data were organized as mean and standard deviation of the mean. Statistically different in the *student t* test applied to unpaired samples, for non- parametric data were determined through the Shapiro-Wilk protocol, with significance level of p≤0,05 (*) and p≤0,01 (**).

DISCUSSION

Based on results, adaptations in morphological methods depend on the adopted method. This finding suggests that tensional resistance training is more efficient to develop strength, whereas the metabolic resistance training is more efficient to achieve good hypertrophic responses. Based on the ACSM, the tensional method is the most efficient to achieve good hypertrophic responses (Ratamess, Alvar *et al.,* 2009; Allegretti , Charro *et al.,* 2018). Authors such as Wilborn, Taylor *et al*. (2009), Neves, Neto *et al*. (2014), Polito, Cyrino *et al*. (2010), Custódio, Mir *et al*. (2011) and Azevedo, Demampra *et al*. (2007), applied this method to many different samples, from sedentary women to trained men. According to their results, this method promotes strength increase, but they did not observe hypertrophic responses, although the method is recommended for such purpose. Results in our experiments (Figure 1 and Table 1) indicates that the tensional method is inefficient to promote significant increase in morphological adaptations and very efficient to increasing the ability to generate force, as well as the results of the authors cited.

The increased strength-manifestation levels indicated greater EGA efficacy (Figure 2 and table 2), given the significant strength increases in comparison to EGB in all the performed exercises, except elbow extension. This outcome reinforces the results found in cited studies (Azevedo, Demampra *et al.,* 2007; Wilborn, Taylor *et al.,* 2009; Polito, Cyrino *et al.,* 2010; Custódio, Mir *et al.,* 2011; Neves, Neto *et al.,* 2014) , which have followed the recommendations by ACSM (Ratamess, Alvar *et al.,* 2009). This method was the most efficient one to increase the strength manifestation levels. On the other hand, results of the anthropometric data comparison (Figure 3) indicated that the metabolic resistance training protocol (EGB) was the most efficient, mainly for muscle weight gain. Similar results were found in experiments performed by Takada, Okita *et al*. (2012), with lower percentage of load (50% of 1RM), repeated for 12 weeks at rigid intervals (30') were efficient to stimulate hypertrophic responses and to increase the strength manifestation levels. Mezzaroba, Ribeiro *et al*. (2014) and Schuenke, Herman *et al*. (2012), applied variations of resistance training programs, exercises with low load and small number of repetitions, and observed body weight and Body Mass Index reduction in young women (Mezzaroba, Ribeiro *et al.,* 2014). The metabolic resistance exercises, with large number of repletion’s (Sobral and Rocha, 2017), have similar biochemical characteristics to those with circulatory occlusion exercises, especially oxidative stress caused by inorganic phosphate accumulation, decreased intramuscular pH and increased reactive oxygen species (ROS) (Takada, Okita *et al.,* 2012).

Anaerobic systems prevail in resistance exercises based on a larger number of repetitions, they make adaptations to the enzymatic activity, mainly to the enzymatic pathways and to the synthesis of new ATP molecules (Cooper and Hausman, 2016). Resistance exercises have modulating signal-generating properties capable of activating a protein complex centered in mTOR (Hall, 2013), which is responsible for controlling protein synthesis and for promoting tissue growth. This protein complex, (mTOR1) plays a central role in skeletal muscle hypertrophy (Pérez-Schindler and Handschin, 2019) when it is associated with the Akt protein, during the intracellular signaling process and when they are simultaneously activated by stimuli from the resistance training; therefore, it increases protein synthesis signaling in muscle cells (Melo, Amadeu *et al.,* 2011). This protein complex signal can integrate environmental signals (resistance training) to cellular mechanisms that induce or regulate hypertrophy (Saxton and Sabatini, 2017). The complex interaction between oxidative stress (cellular metabolism) increases the intracellular signaling to enzymatic protein transcription and high energy phosphates (ATP) (Takada, Okita *et al.,* 2012). Increased intracellular ATP concentration activates mTOR signaling pathways (Ito, Ruegg *et al.,* 2018), which is the main regulatory hypertrophy pathway, mainly when Akt is activated all together (Melo, Amadeu *et al.,* 2011). These pathways lead to greater, and more efficient, stimuli for the hypertrophic protein synthesis of the skeletal muscle (Saxton and Sabatini, 2017).

Conclusion

Based on the results, it is possible stating that morphological adaptations depend on the adopted resistance training method; moreover, the metabolic resistance training method is the most effective to achieve good hypertrophic responses. On the other hand, the tensional method is more efficient to increase the capacity to generate force. It is necessary to replicate these protocols in different samples to test the reproducibility of the recorded results, given the profile of the subjects composing the sample.

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