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Impact of nutritional status on body composition and muscle strength of older women enrolled in a resistance training program

Impacto do estado nutricional na composição corporal e força muscular de idosas inseridas em um programa de treinamento com pesos

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Abstract – Overweight among older adults has increased considerably, and resistance training (RT) is a very attractive intervention strategy for positive changes associated with its practice. The aim was to evaluate the impact of nutritional status on body composition and muscle strength of older women in a RT program. Forty-eight older women were divided into three groups: eutrophic (EUT, BMI ≤ 24.9 kg/m²), overweight (OVE, BMI between 25.0 and 29.9 kg/m²) and obese (OBE, BMI ≥ 30.0 kg/m²). RT was performed for 12 weeks, one set of 10 to 15 repetitions, eight exercises, three weekly sessions. Body composition assessments (muscle mass, fat mass and trunk fat), strength and muscle quality were performed. Interaction for muscle mass in EUT had significant effect (+ 4.0%) when compared to OVE (+ 1.4%) and OBE (+ 1.4%). Time effect was observed for muscle strength (EUT = + 10.6%, OVE = + 7.5% and OBE = + 11.0%), muscle quality (EUT = + 6.1%, OVE = + 6.3% and OBE = + 9.8%), trunk fat (EUT = - 3.3%, OVE = - 0.7% and OBE = - 0.7%) and fat mass (EUT = - 3.0%, OVE = - 1.5% and OBE = - 0.5%). The results suggest that RT is effective for improving strength, muscle quality, muscle mass, trunk fat and fat mass of older women, but nutritional status may be determinant in muscle mass changes.

Key words: Adiposity; Exercise; Health of the elderly; Resistance training.

Resumo – *O objetivo do presente estudo foi avaliar o impacto do estado nutricional na composição corporal e força muscular de idosas inseridas em um programa de treinamento com pesos (TP). Quarenta e oito idosas foram divididas em três grupos: eutróficas (EUT, IMC ≤ 24,9 kg/m²), sobrepeso (SOB, IMC entre 25,0 e 29,9 kg/m²) e obesas (OBE, IMC ≥ 30,0 kg/m²). O TP foi realizado por 12 semanas, uma série de 10 a 15 repetições, oito exercícios, três sessões semanais. Avaliações da composição corporal (massa muscular, massa gorda e gordura de tronco), força e qualidade muscular foi realizado. Interação foi encontrada para a massa muscular onde o grupo EUT apresentaram efeito significativo (+ 4,0%) quando comparado ao SOB (+ 1,4%) e OBE (+ 1,4%). Efeito do tempo foi observado para a força muscular (EUT = + 10,6%, SOB = + 7,5% e OBE = + 11,0%), qualidade muscular (EUT = + 6,1%, SOB = + 6,3% e OBE = + 9,8%), gordura de tronco (EUT = – 3,3%, SOB = – 0,7% e OBE = – 0,7%) e massa gorda (EUT = – 3,0%, SOB = – 1,5% e OBE = – 0,5%). Os resultados sugerem que o TP é efetivo para a melhora da força, qualidade muscular, massa muscular, gordura de tronco e massa gorda de mulheres idosas, porém o estado nutricional pode ser determinante nas modificações da massa muscular.*

Palavras-chave: *Adiposidade; Exercício; Saúde do idoso; Treinamento de resistência.*

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INTRODUCTION

The prevalence of overweight and obesity among older adults has increased considerably in recent decades[1]. This information is alarming when analyzing the current conditions in Brazil. Data from the Family Budgets Survey[2] shows that 70% of the Brazilian population over 65 is overweight or obese. Such conditions are predominant in women, where 76% are overweight. Excess weight is related to insulin resistance, hypertension and dyslipidemia, which are metabolic risk factors for cardiovascular diseases and diabetes mellitus[3]. In addition, overweight plays an important role in the physical incapacity among these individuals[4].

Weight reduction leads to metabolic and functional benefits[5] for the elderly population. However, a possible disadvantage of weight loss in the elderly is the reduction of muscle mass, which may accelerate the development of sarcopenia[6]. Muscle mass and strength reduction impairs activities of the daily living and is associated with increased risk of falls and reduced body functions[1,4,6]. Therefore, although overweight older adults can benefit from weight loss, treatment should focus on minimizing loss of muscle mass to preserve independence and quality of life[7-8].

Thus, based on the numerous benefits reported in literature[5-9], regular practice of resistance training has been widely recommended, especially for elderly individuals, since it is considered a non-pharmacological intervention strategy that is very attractive in mitigating the deleterious effects related to the aging process[7-8]. Among the main modifications associated with resistance training practice are: muscle strength gains[9] and increased muscle mass[7-8,] reduction of body fat[7-9] and also improvement in muscle quality[8].

Such positive modifications have been observed in eutrophic, overweight and obese older adults[7-11]. However, recent studies[7-11] have shown the influence of resistance training on the elderly in isolation, not observing the effectiveness of training when individuals are classified in different nutritional status. Nutritional status is an interesting clinical strategy in professional practice, since it observes the body mass distribution in older adults, the analysis of the effectiveness of resistance training in individuals with different nutritional status can assist both in the training prescription, in the clinical follow-up for body mass reduction in overweight older adults[7-11].

The great variability of results found in literature indicates that, possibly, eutrophic, overweight and obese individuals should have different adaptive responses when performing similarly resistance training. Ribeiro et al.[8] observed that after eight weeks of resistance training in overweight older women, a 1.4% increase in muscle mass and 5.0% in muscle strength was verified. Tomeleri et al.[7] observed in obese older women that, after eight weeks of resistance training, increases in muscle strength and muscle mass were in the order of 11.5% and 4.3%, respectively. It is worth mentioning that in the study by Ribeiro et al.[8] and Tomeleri et al.[7], the maintenance of eating habits was analyzed.

Therefore, since resistance training may be related to the magnitude of responses observed in body composition and muscle strength in the elderly, with possible association of nutritional status, the aim of the present study was to evaluate the impact of nutritional status on body composition and muscle strength of older women enrolled in a resistance training program.

METHODOLOGICAL PROCEDURES

Experimental design

The present study was developed using database produced by the following project: "Impact of different weekly frequencies on resistance training in older women", partially funded by the National Council for Scientific and Technological Development (CNPq) (Protocol No. 486371/2011-5). The study had total duration of 17 weeks, where weeks 1 to 3 were intended for initial assessments (pre-training), weeks 4 to 15 intervention with resistance training practice, and weeks 16 and 17 for final evaluations (post training).

Participants

Sixty older women aged 60 or over were selected to participate in the study. The sample was preliminarily selected through interviews and clinical anamnesis, which verified the willingness to practice physical activities and activities of the daily living, and were divided into three groups: eutrophic (n = 20, body mass index ≤ 24.9 Kg/m^2, 71.2 ± 6.7 years, 55.3 ± 6.6 kg, 156.3 ± 6.4 cm, 22.5 ± 1.4 kg/m^2), overweight (n= 20, body mass index between 25.0 and 29.9 kg/m^2, 64.8 ± 2.5 years, 66.2 ± 5.6 kg, 154.1 ± 5.6 cm, 27.8 ± 1.1 kg/m^2) and obese (n = 20, body mass index ≥ 30.0 kg/m^2, 68.5 ± 5.7 years, 84.0 ± 12.4 kg, 157.1 ± 6.9 cm, 33.9 ± 3.1 kg/m^2), adopting as classification the body mass index proposed by the World Health Organization[12].

As inclusion criteria for participation in this study, participants should: (1) be physically independent; (2) not undergoing hormone replacement therapy; and (3) absence of heart disease. It is worth mentioning that individuals did not practice regular resistance training for at least 24 weeks (untrained). Participants were only included in the study after being evaluated by a cardiologist and released without restriction to participate in physical exercise programs.

Older women who did not participate in at least 80% of training sessions during the intervention period or who were absent for five consecutive sessions were excluded from the statistical analysis. Twelve participants were excluded from the analysis for the following reasons: travel, family problems, health problems and surgeries not related to resistance training and unavailability to participate (work).

This study was approved by the Ethics Research Committee of the Londrina State University, according to Resolution 466/2012 of the National Health Council on research involving human beings (Protocol: 048/2012 and Process: 10656/2012). After being completely clarified about the study proposal and procedures to which they would be submitted, participants signed the Free and Informed Consent Form.

Eating habits

Three-day food records were used to monitor eating habits (two week days and one weekend day). Participants were instructed by a previously trained nutritionist on filling in food records during the first and last week of intervention and were also instructed how to identify the portion size of foods consumed, including beverages, using standardized home measures. The total energy intake and the ingested proportions of macronutrients were determined through the Avanutri nutritional assessment program (Processor Nutrition Software, Rio de Janeiro, Brazil; Version 3.1.4). All participants were instructed not to change their eating habits throughout the study. Water intake was *ad libitum*.

Body composition

Dual energy X-ray absortometry (DXA) was used to evaluate body composition. DXA measurements were performed on a Lunar Prodigy brand equipment model Healthcare GE ID 14739 (Madison, WI, USA) using full body scanning. After full body scan, the program provided estimates of lean tissue, fat mass, and trunk fat. Muscle mass was calculated from the quantification of lean and soft appendicular tissue using the predictive equation of Kim et al.[13]. Previous measurements (test-retest) were obtained in nine participants with a 24-h interval between them, which resulted in a standard error of estimation (SEE) of 0.29 kg and 0.90 kg for muscle mass and fat mass, respectively, and intraclass correlation coefficient (ICC) of 0.99 and 0.98 for muscle mass and fat mass, respectively.

Muscle strength

Muscle strength was determined by a maximal repetition test (1RM) in three exercises. Exercises were tested in the following order: vertical bench press, leg extension machine and biceps curl, respectively. The methodological procedures followed the proposal of Nascimento et. al.[14]. The sum of the total load used in the three exercises was used as muscle strength indicator. Reproducibility measurements were obtained on vertical bench press (SEE = 0.46 kg and ICC > 0.97), leg extension machine (SEE = 1.67 kg and ICC > 0.91) and biceps curl (SEE = 0.93 kg and ICC > 0.93).

Muscle quality

The representation of improvement in the neural component was indicated by the muscle quality index, which was determined by dividing the total muscle strength determined by the sum of the three 1RM exercises by the muscular mass predicted by DXA[15].

Resistance training

The resistance training program lasted 12 weeks and was based on recommendations for the elderly[16] to improve muscle strength and endurance. Training was conducted during three weekly sessions on non-consecutive days (Mondays, Wednesdays and Fridays) in the morning. In order to standardize the movement pattern and provide safety, all participants were individually instructed by Physical Education teachers and undergraduate students.

The resistance training program was structured to stimulate the different body segments (upper limbs, trunk and lower limbs), which consisted of the execution of one set of 10 to 15 repetitions. Eight exercises were performed during the study in the following order: vertical bench press, horizontal leg press, articulated rowing, leg extension machine, biceps curl, leg curl, pulley triceps and calf machine. The recovery interval between exercises was one to two minutes.

The loads used were compatible with the repetition intervals stipulated for each exercise, being determined after the performance of each participant in the familiarization sessions and individually adjusted throughout the experimental period whenever the upper limit of repetitions predetermined for each exercise were reached during two consecutive sessions. Thus, increments of 2-5% for upper limb exercises and 5-10% for lower limb exercises were used[16], so that the initial training intensity was preserved throughout the intervention period. During the execution of movements, participants were instructed to inspire in eccentric muscular action and to exhale in the concentric muscular action, maintaining the speed of execution of movements at 1:2 ratio in the concentric and eccentric phase, respectively. All participants were instructed to maintain normal levels of physical activity throughout the study and not to initiate new physical exercise programs during the trial period.

Statistical analysis

To guarantee the reliability of data, statistical procedures were performed after the preliminary study of variables related to normality and equality of variance between groups, with statistical power of 80% for comparisons evaluated. The Shapiro Wilk test was used for the analysis of data distribution and the Mauchly test for sphericity analysis. Analysis of variance (ANOVA) for repeated measurements was performed for intra and intergroup comparisons of muscle strength and muscle quality. For variables (total caloric value, carbohydrate intake, protein intake, lipid intake, muscle mass, trunk fat and fat mass), which differences occurred between groups in the pre-training analysis, covariance (ANCOVA) using the pre-training measure as covariate was performed. The Fischer *post hoc* test was used to identify specific differences in variables whose F values found were higher than the established statistical significance criterion ($p < 0.05$). STATISTICA statistical package for Windows, version 10.0 (StatSoft Inc, Tulsa, OK, USA) was used for data analysis. The magnitude of differences was calculated from the effect size (ES)[17].

RESULTS

The eating habits of study participants before and after 12 weeks of resistance training are presented in Table 1. Time effect ($p < 0.05$) was observed

Table 1. Eating habits before and after 12 weeks of resistance training in eutrophic, overweight and obese individuals (n = 48). Values are expressed as mean ± standard deviation.

	Eutrophic (n = 16)	Overweight (n = 16)	Obese (n = 16)	Effect	F	p
TCV (kcal/kg/day)				Group	2.03	0.14
Pre	33.74±2.04	26.31±2.04	21.69±2.04	Time	6.54	< 0.01
Post	36.50±1.99*	28.66±1.99*	23.35±1.99*	Interaction	0.13	0.88
CHO (g/kg/day)				Group	2.52	0.09
Pre	5.26±0.34	3.98±0.34	3.38±0.34	Time	1.15	0.29
Post	5.36±0.32	4.40±0.32	3.37±0.32	Interaction	0.66	0.52
PTN (g/kg/day)				Group	1.51	0.23
Pre	1.33±0.09	1.12±0.08	0.90±0.09	Time	0.01	0.99
Post	1.32±0.08	1.13±0.07	0.89±0.09	Interaction	0.01	0.99
LIP (g/kg/day)				Group	4.41	0.07
Pre	0.84±0.06	0.69±0.06	0.57±0.06	Time	15.24	< 0.01
Post	1.08±0.07*	0.73±0.07*	0.68±0.07*	Interaction	2.94	0.06

TCV = total caloric value. CHO = carbohydrates. PTN = proteins. LIP = lipids. Eutrophy = BMI ≤ 24.9 kg/m^2. Overweight = BMI between 25.0 and 29.9 kg/m^2. Obesity = BMI ≥ 30.0 kg/m^2. * Difference in relation to pre-training ($p < 0.05$).

for total caloric value (eutrophic = + 8.2% [ES = 1.35], overweight = + 8.9% [ES = 1.15] and obese = + 7.7% [ES = 0.81]) and lipid intake (eutrophic = + 28.6% [ES = 4.00], overweight = + 5.8% [ES = 0.67] and obese = + 19.3% [ES = 1.83]). The observed effect was classified as moderate (lipid intake for the overweight group) at high magnitude (lipid intake for the eutrophic group). No significant effects were found for carbohydrate and protein intake ($p > 0.05$).

The behavior of muscle mass, fat mass, trunk fat, muscle strength and muscle quality of study participants before and after 12 weeks of intervention is presented in figure 1. Group x time interaction ($F = 4.73$ and $p < 0.01$) was found for muscle mass, where the eutrophic group had significant effect (+ 4.0%, ES = 1.09) when compared to the overweight (+ 1.4%, ES = 0.38) and obese groups (+ 1.4%, ES = 0.48). Time effect was observed for muscle strength ($F = 97.42$ and $p < 0.01$, eutrophic = + 10.6% [ES = 2,14], overweight = + 7.5% [ES = 1.51] and obese = + 11.0% [ES = 2.45]), muscle quality ($F = 51.69$ and $p < 0.01$, eutrophic = + 6.1% [ES = 1.70], overweight = + 6.3% [ES = 1.70] and obese = + 9.8% [ES = 2.40]), trunk fat ($F = 5.45$ and $p < 0.01$, eutrophic = - 3.3% [ES = 0,39], overweight = - 0,7% [ES = 0,14] and obese = - 0,7% [ES = 0,20]), and fat mass ($F = 5.36$ and $p < 0.03$; eutrophic = - 3.0% [ES = 0,38], overweight = - 1,5% [ES = 0.31] and obese = - 0.5% [ES = 0.15]), where all groups were modified throughout the experiment. The observed effect was classified as small (fat mass for the obese group) to great magnitude (muscle quality for the obese group).

Figure 2 shows individual relative changes in muscle strength, muscle quality, muscle mass, fat mass, and trunk fat of participants after 12 weeks of resistance training. It is worth mentioning that 92% of participants submitted to resistance training were responsive to muscle strength (panel A). Muscle quality (panel B), muscle mass (panel C), fat mass (panel D)

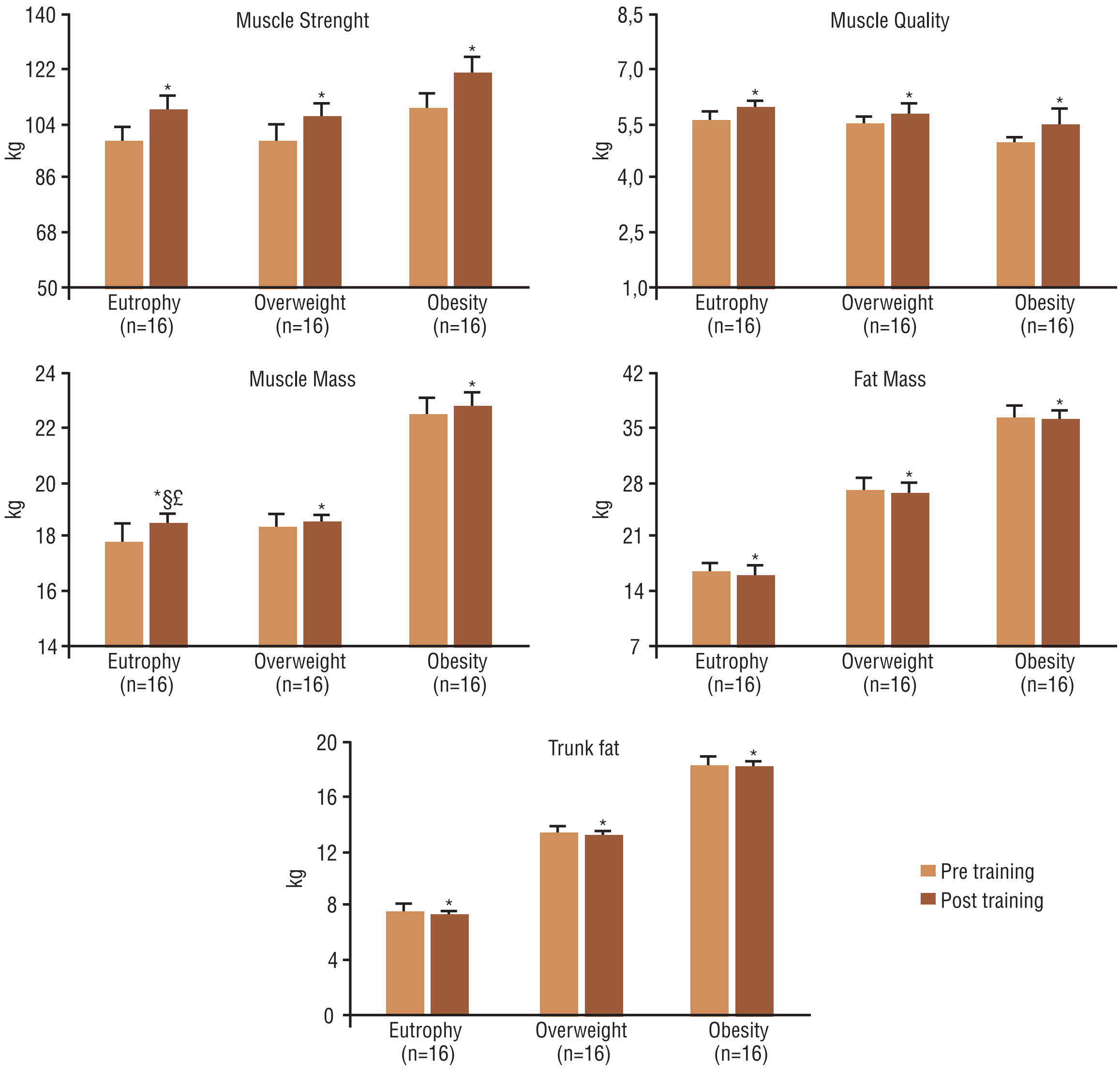

Figure 1. Muscle strength, muscle quality and body composition (muscle mass, fat mass and trunk fat) before and after 12 weeks of resistance training in eutrophic, overweight and obese older women (n = 48). Values are expressed as mean ± standard deviation. *Difference for pre training ($p < 0.05$). §Difference for overweight group ($p < 0.05$). £Difference for obese group ($p < 0.05$).

and trunk fat (panel E) measures revealed training responsiveness with weights of 90%, 81%, 63% and 73%, respectively. Regarding groups, 90% of the eutrophic group, 72% of the overweight group and 76% of the obese group were responsive to resistance training.

DISCUSSION

The main finding of the present study was that older eutrophic women are more responsive to changes in muscle mass when enrolled in a resistance training program. However, the 12-week resistance training period also resulted in decreased fat mass and trunk fat, increased muscle strength, muscle mass, and muscle quality in overweight and obese participants. To our knowledge, this is the first study that compared the effect of resistance training on older women classified in different nutritional status.

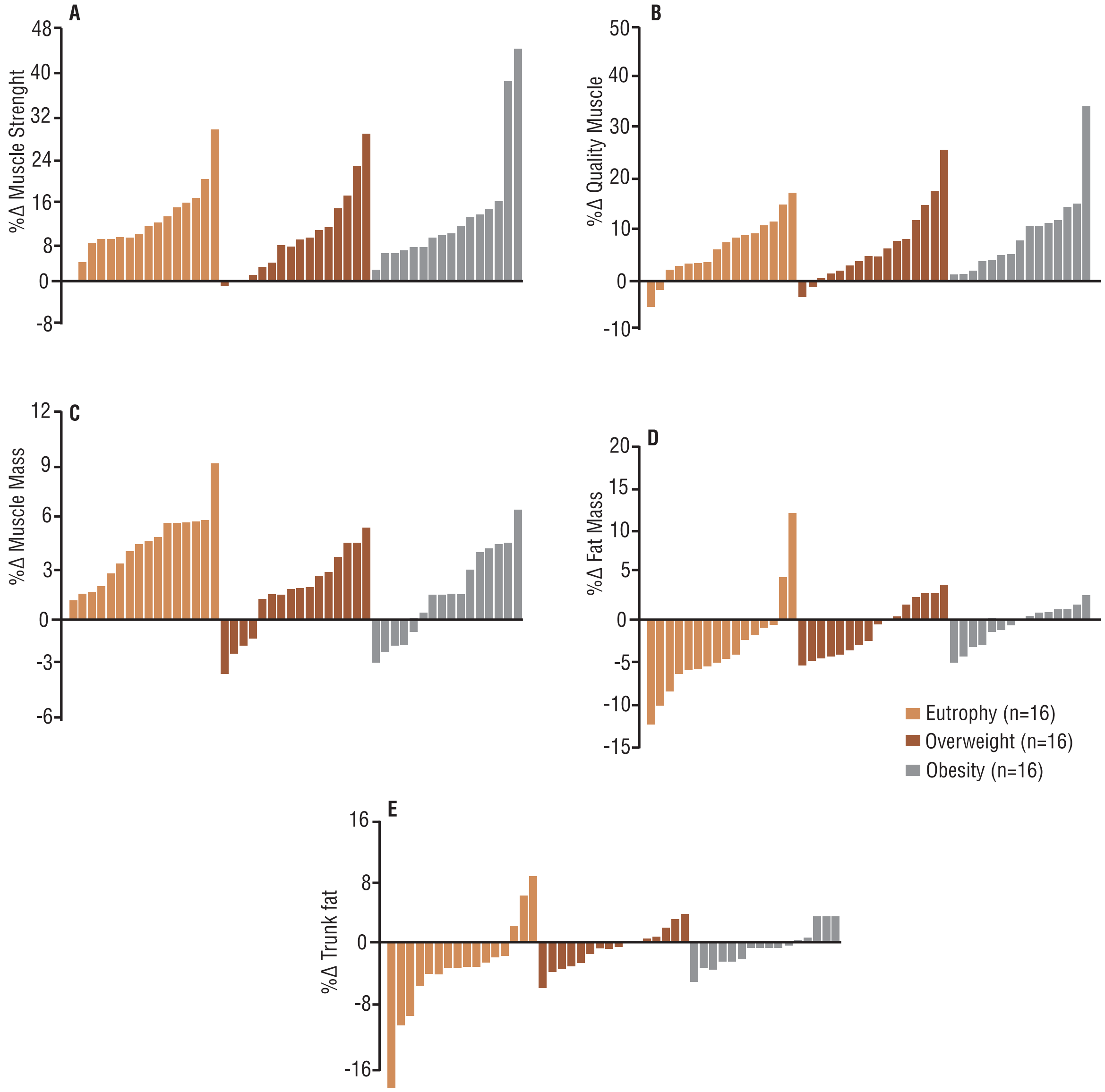

Figure 2. Relative changes in muscle strength (A), muscle quality (B), muscle mass (C), fat mass (D) and trunk fat (E) after 12 weeks of resistance training in eutrophic, overweight and obese older women (n = 48).

The results confirm that regular resistance training may be beneficial for muscle strength and body composition in untrained older women, providing them with greater protection against various harmful effects caused by the aging process[18-19].

Although maintaining and/or increasing muscle mass with resistance training programs has been reported in studies with older overweight and obese adults[8,10], our findings have demonstrated that such responses may be influenced by the sample characteristics, since eutrophic women were more responsive to resistance training when compared to overweight and obese ones. The findings pointed to increases in muscle mass with responsiveness level of 81% among participants. These findings are consistent with recent literature data, which point to the effectiveness of resistance training in the muscle mass of older adults[7-9].

A possible determinant factor for changes in muscle mass is related to the amount of body water[8], which can be explained as an adaptive response associated with increased muscle glycogen reserves stimulated by resistance training. Each gram of glycogen stored in the muscle attracts three water molecules, increasing the water inflow from the extracellular medium to the intracellular medium, a phenomenon that favors hyperhydration of muscle tissue, which can mediate a chronic hypertrophic response through different pathways[20]. In this sense, although the mechanisms by which increased cellular hyperhydration promotes hypertrophy are not known, there are reports that this increase can stimulate the proliferation of satellite cells and facilitate their fusion to myofibrils[20], stimulating not only the increase of protein synthesis, as well as decreased proteolysis.

Another factor observed in the present experiment is related to the amount of food ingested by the different groups. Participants classified as eutrophic, although not presenting statistical significance, performed higher caloric intake of carbohydrates, proteins and lipids when compared to the group of obese and overweight women. The latest dietary guidelines for health of the International Society of Sports Nutrition[21-23] point out that for healthy people who exercise, eating habits should be based on the intake of macronutrients in the following proportion: 8 to 12 g/day of carbohydrates, 1.4 to 2.0 g/day of proteins and ≤ 30% of lipids. Hypercaloric diets assist in muscle mass modifications, especially with adequate protein intake, as observed by the eutrophic group[10].

Excess body fat, especially in the central region of the body, is related to the development of innumerable metabolic and cardiovascular disorders, and one of the strategies to control it is the participation in physical exercise programs[7]. The findings of the present study indicated that resistance training was effective in reducing fat mass (63% responsiveness) and trunk fat (73% responsiveness), regardless of nutritional status.

Previous research has already shown a decrease in body fat after resistance training sessions[7-8]. Although some researchers argue that body fat reduction can be attributed to the increase in muscle mass and its relationship with the resting metabolic rate[24], such hypothesis could not be confirmed in this study. Another factor to consider is that some resistance training protocols can produce increases in post-exercise oxygen consumption[25] and perhaps contribute to long-term body fat changes.

In the present study, time effect was revealed for muscle strength. It is worth mentioning that increases in muscular strength are consistent with literature[7-8], indicating that the training load progression model was adequate, not allowing the establishment of the plateau effect, quite common in resistance training programs. This condition indicates that even participants using only one set per exercise during the 12 weeks of intervention was enough to modify the muscle strength of untrained individuals. Although data from our laboratory[7-10,26] have already demonstrated the effect of using multiple sets to increase muscle strength in the elderly, to our knowledge, this is the first study to demonstrate the effectiveness of the progression of single set on the muscle strength components of older women classified in different nutritional status, with 92% responsiveness.

The relationship between muscle strength and volume is indicated as muscle quality, which reflects strength per muscle mass unit[27]. Muscle quality indexes may contribute to the diagnosis of sarcopenia[27] and are used in the evaluation of physical exercise programs to reduce fragility and functionality in the elderly[27-28]. Improvements in muscle quality may reflect favorably on common tasks of the daily living, such as carrying objects more safely or simply feeding. Mechanisms related to improving muscle quality are complex and not fully understood. However, it is speculated that the advances may be related to factors such as neural adaptations, increase of the transversal muscular area, increase of muscular power, increase of contractile protein, increase in the length of the fascicle at rest due to the addition of sarcomeres in series, innervation, changes in muscle architecture and/or reduction of intramuscular fat deposits[27].

Even with the positive findings of the present study, on the other hand, some important limitations should be pointed out. The absence of electromyographic analysis hinders a more robust appreciation of muscular strength behavior as well as muscle quality. Dietary habits were not controlled, which may have influenced in part the responses associated with muscle mass gains and reduction of total body and trunk fat. In addition, the lack of follow-up of levels of physical activity outside the study environment may have partially compromised our findings, since literature has pointed out that the level of physical activity may be an important determinant for health in the elderly[29-30].

CONCLUSION

The results suggest that resistance training is effective for improving strength, muscle quality, muscle mass, trunk fat and fat mass of older women, but nutritional status can be determinant in muscle mass changes.

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