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ORIGINAL ARTICLE

EFFECTS OF MUSCULAR HYPERTROPHY AND AEROBIC TRAINING IN OBESE SUBMITTED TO BARIATRIC SURGERY

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Objectives: To assess muscle strength (MS), functional capacity (FC) and body composition and correlate these variables in obese individuals after bariatric surgery before and after a training program. **Methods:** 18 obese subjects, average age 40.8 ± 9.2 years, 60 days post-operative (PO) bariatric surgery had MS estimated at 10 maximum repetitions test and the handgrip dynamometer force (HDF). FC was evaluated by the vertical displacement test (VDT) and maximum muscle power (MMP). The training program consisted of supervised combined muscle hypertrophy and aerobic exercise 2 days/week for 36 weeks, including 6 exercises with large muscle groups, doing 1-3 sets, 10-12 repetitions and 25 minutes of aerobic exercise. Whole-body densitometry was used to assess the percentage and absolute values of lean mass (LM) and fat mass (FM) totals. We used paired T-student's test and Pearson's correlation, and $p<0.05$ for statistical significance. **Results:** There was significant reduction of anthropometric variables after training ($p<0.0001$). The LM percentage increased significantly in upper and lower limbs, and trunk (thorax) ($p<0.0001$). There were also increases in HDF, MMP and MS ($p<0.05$), a reduction in VDT performance time ($p<0.0001$). High and positive correlations were found between MS and LM in lower and upper limbs ($r> 0.80$; $p<0.0001$). **Conclusion:** The combined program of muscle hypertrophy and aerobic exercises promoted significant increases in overall and localized MS, improved functional performance and helped to ensure a reduction of LM loss, which is very common in the PO period of this surgery.

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INTRODUCTION

The presence of morbid obesity leads to various osteomuscular damage such as osteoarthritis, poor posture, back pain and increased risk of injury and falls, limiting functional mobility of the obese; and when associated with a sedentary lifestyle, it contributes to low self-esteem, thus deteriorating the quality of life of individuals even more[1-5].

Another limitation found in the obese relates to a reduction in aerobic and anaerobic functional capabilities. Aerobic capacity is related to the performance of longer exercises of mild to moderate intensity, while anaerobic capacity is related to the ability to perform shorter and vigorous exercises, such as those related to some activities of daily living such as running to catch bus, climbing up stairs quickly, etc.[1]

Although it is believed that excess weight is associated with increased muscle strength, beneficial effects on bone mass and preventing osteoporosis, some studies have shown that the obese have greater absolute muscle strength than normal weight individuals[1,6]. However, when this strength is expressed in relation to body weight, it becomes smaller than that observed in normal individuals, in both men and women. The limitation of physical performance, along with obesity can lead to reduced muscle strength, which further compromises functional activities in this population[7,8].

In order to minimize these limitations, bariatric surgery has been a satisfactory alternative to induce long lasting weight reduction[4,5]. In the post-operative (PO) period, improved cardiopulmonary, orthopedic and metabolic function have been observed, along with increased tolerance to efforts thus reducing pain and limiting symptoms due to the osteoarticular wear/stress caused by excess weight, contributing to a more satisfactory quality of life[9-12].

Despite the resulting benefits with surgery, rapid weight reduction contributes to greater depletion of total body mass and fat mass (FM) and may also result in a reduction of lean mass (LM)[13]. This condition can lead to functional impairments, such as decreased strength, power, muscle resistance, and worsening of pre-existing muscle conditions[4,5].

Several studies have indicated practicing regular exercise in the PO of bariatric surgery[4,5,14,15], in order to promote weight loss, LM gain and muscle strength, and to facilitate effective adherence with changes to a healthier lifestyle. Most studies involve different types of surgical procedures, they have an observational nature and physical activity is measured by specific questionnaires and is self-reported; methods that can contribute to overestimate the participation of the obese in these types of activities and hinders specific analysis of the protocol[3,15]. Thus, literature lacks more homogeneous, randomized and clearer evidence on the intensity, duration and types of exercises that are more specific for this population[3].

The literature has suggested alternative tests to estimate strength in specific muscle groups[16-18]. The use of an isokinetic dynamometer, considered the "gold standard" for measuring this variable, is little disseminated in clinical practice due to its high cost and the need for specialized equipment to take the measurement[16,18]. In clinical practice, this variable can also be measured by the 1 maximum repetition test (1MR) or estimated by submaximal tests such as the 10MR test[17].

Given the above, there is the need to use reliable and reproducible tests for monitoring the obese population and a more quantitative assessment of strength, power, hypertrophy and muscular endurance parameters. Thus, we hypothesized using a training program that includes standardized muscle hypertrophy exercises and aerobic training with good tolerance, which enables significant gains in muscle mass without the risk of musculoskeletal and cardiovascular burden for the obese population.

Thus, with the information detailed above the objective of this study was to evaluate muscle strength, functional capacity and body composition and correlate these variables in obese patients submitted to bariatric surgery before and after a combined physical training program of muscle hypertrophy exercises and aerobic training.

MATERIALS AND METHODS

This is a study of pre-post design evaluating muscle strength and functional variables of obese at 60 days PO of bariatric surgery. This study was conducted in the Clinical School of the University Center of Belo Horizonte (UNI-BH) from August 2010 to August 2013, after approval by the Research and Ethics Committee of the Uni-BH (protocol 023/2009).

The sample was composed of 18 obese volunteers of both genders between the ages of 20 and 60 years, who had undergone bariatric surgery (Roux-En-Y gastric bypass), later being recruited to participate in a joint training muscle hypertrophy and aerobic exercise program for 36 weeks.

Exclusion criteria were individuals who had the presence of uncontrolled cardiovascular disease such as heart failure, diabetes or high blood pressure, or uncontrolled previous pulmonary disease with chronic bronchitis or orthopedic limitations (reports of limiting pain in knees, ankles or hips and/or previous diagnosis of knee osteoarthritis) that contraindicated effort.

The volunteers were submitted to an initial physical therapy evaluation consisting of anamnesis, measurement of anthropometric variables: weight (kg), height (m), body mass index (kg/m^2) and waist circumference, 10MR test to estimate the initial training load, handgrip test, vertical displacement test (VDT) to assess functional capacity and body composition evaluation by whole-body densitometry.

Body weight and height were measured by WELMY 150 kg 100CH commercial mechanical scale (WELMY Brand, WELMY manufacturer, São Paulo, Brazil). Waist circumference was measured with the aid of a measuring tape, being measured at the midpoint between the last rib and the upper edge of the iliac crest, with volunteers in standing position[19].

10MR Test

10MR test consists of estimating the strength of localized/ specific muscle groups. A test is conducted to assess the maximum load supported by volunteers performing ten maximum repetitions (10MR) in specific exercises. All 18 volunteers were subjected to determination of the load on the following devices: lower limbs (LL): leg curl, leg extension chair and leg press; and for upper limbs (UL): lat pull down, bench press and rowing from MANEJO FITNESS (*TIGRA Ind. Com. de Equipamentos de Ginástica Ltda,* Divinópolis, MS, Brazil.). (Figure 1)

Figure 1. Volunteer performing hypertrophy training on the a) Leg press; b) Leg curls and c) Lat pull down

A series of warming up exercises was carried out before the test (4-6 free repetitions) with the lowest possible load or approximately 50% of the load which would be used in the first trial. After this preparatory phase, the test began with a low load (5.0 kg to 10.0 kg for UL and LL) with increases of 5.0 to 10 Kg used in progression until determining maximal load. The Borg Rating of Perceived Exertion Scale (RPE)[20] was used to facilitate the increments of load, with ratings ranging from 6 ("very, very easy") to 19 ("exhausting"), in order to assess the individual's tolerance for each load. The test was stopped when the volunteer did not tolerate performing 10MR of a specific load or when they reported exertion as "very hard or exhausting".

If the volunteer did not tolerate doing 10MR at a given load, the load that had been previously achieved was registered. The load was adjusted to 10MR with maximum 5 attempts for each device. Exercises were alternated between UL and LL to ensure a more complete muscle recovery between each attempt. Each repetition was performed at a speed of 1: 2 seconds, and the rest time was 2 minutes between each load[17].

Handgrip Strength Evaluation:

Muscle strength was assessed by a JAMAR® hydraulic dynamometer (California, USA, 1998). The volunteer sat with adducted shoulder, elbow flexed at 90°, forearm in neutral position, wrist between 0 and 30° of extension and was instructed to press the dynamometer as hard as they could after the verbal command "Attention! Now!" Three measurements were alternately made on each hand, and the greatest measurement between the two hands was considered as the effective test result. Prior to the maximum measurement, 3 submaximal strength measurements were done as a warm-up[21].

Assessment of functional capacity - vertical displacement test:

Maximum muscle power (MMP) or anaerobic alactic of the lower limbs of the volunteers was assessed using the VDT, which was adapted from Sartorio et al.,[8] (2004) for obese individuals.

To calculate MMP, the following formula was used: $W = (Wbgh)/t$, in which Wb is body weight of the subject (in kg), g is the acceleration of gravity (9.81ms^{-1}), h is the total vertical distance covered during the test (in meters) and t is the elapsed time (in seconds) to cover the distance[8].

Subjects were instructed to climb a staircase of 13 steps, each of 15.8cm, at the fastest possible speed, totaling 2.06m vertical distance. The individual was about 10 cm away from the first step to start the test. One of the evaluators measured VDT runtime through a TECHNOS® digital stopwatch (GRUPOTECHNOS, Manaus, Brazil). The test started when the dominant foot was placed on the first step and ended when that same foot came into contact with the last step. The volunteers familiarized themselves with the technique before starting the test through a practice training. Two VDT were performed with a 5 minute rest period between each measurement. The lowest time obtained for VDT was recorded and MMP was calculated for data analysis.[8]

Combined protocol of Muscle Hypertrophy and Aerobic Training:

After the 10MR test, the highest values obtained for each muscle group were considered as initial load. This activity consisted of conducting supervised muscle hypertrophy and aerobic exercises 2 times per week on non-consecutive days for a period of 9 months (36 weeks). This protocol took 5 to 10 minutes of initial mild intensity exercises (walking), 45-60 minutes of muscle hypertrophy exercise and eccentric contractions, being 1-3 series of 10-12 repetitions involving six types of exercises, similar to those used in the 10MR test. After muscle training, 25 minutes of continuous aerobic exercise was performed at moderate intensity on a treadmill or a MOVIMENT® electromagnetic bike (*Brudden Equipamentos Ltda, Pompéia,* SP, Brazil).

Heart rate (HR) was constantly measured by FS1 heart rate monitor (POLAR) throughout all the activities, and blood pressure (BP) and RPE were monitored at the beginning, middle and end of the session. HR should not reach values higher than 85% of maximum heart rate expected for the age (HR_{max} = 220-age) during test or training.

Each volunteer was trained for 6 weeks with the load obtained in the 10MR test, and had a weekly progression in the number of sets and repetitions. In the first week they trained with 1 set of 10 repetitions, with 2 sets of 10 repetitions in the following week, 3 sets of 10 repetitions in the third and fourth weeks, and 3 sets of 12 repetitions in the last two weeks (5th and 6th), totaling 36 repetitions for each set. The volunteers were reassessed every six weeks, and also performed the 10MR test for a new estimate of muscle strength.

Densitometric evaluation:

Densitometric evaluation was performed on all participants to measure percentage and absolute values of FM and LM for the sample using a i-LUNA DEXA apparatus with software version 11.4 (General Electric Company, Houston, USA).

All variables were reassessed at the end of the training period and the volunteers underwent a new full-body densitometry to obtain the same initial parameters.

STATISTICAL ANALYSIS

Normal data distribution was assessed by the Shapiro-Wilk test. Pre- and post-training comparisons were made via Student's T-test. Pearson correlation test was used to evaluate the association between the variables of strength and LM at the end of training. The significance level was set at p <0.05 and the data expressed as mean ± standard deviation.

RESULTS

The sample consisted of 18 volunteers who participated in a program of muscle hypertrophy and aerobic exercise for 36 weeks, where 85% were women with a mean age of 40.8 ± 9.2 years.

Table 1 shows the clinical and anthropometric characteristics of the sample, in which reduction of weight, BMI, WC and FM percentage (p<0.0001) can be observed. Although the absolute value of LM showed a reduction after training (p=0.001), significant increases in the percentage of LM were observed (p<0.0001).

Table 1: Clinical and anthropometric characteristics of the sample pre- and post-training.

VARIABLES	PRE-TRAINING	POST-TRAINING
Age (years)	40.8 ± 9.2	
Gender	3M and 15F	
Weight (kg)	91.0 ± 9.7	73.6 ± 8.1*
BMI (kg/m	34.6 ± 2.5	28.0 ± 2.25*
WC (cm)	111.4 ± 7.8	92.0 ± 6.5*
Fat mass (%)	48.09 ± 6.54	33.29 ± 6.87*
Lean mass (kg)	47.00 ± 4.52	44.33 ± 5.07
Lean mass UL (%)	50.12 ± 8.32	66.17 ± 7.48*
Lean mass LL (%)	51.61 ± 8.62	67.25 ± 8.74*
Lean mass torso (%)	50.28 ± 5.37	63.64 ± 6.73*

Data expressed as mean ± standard deviation. WC: waist circumference; BMI: body mass index; LL: lower limbs; UL: upper limbs. *p<0.0001 and #p=0.001 comparisons pre- and post-training, via paired Student's t-test.

Regarding functional performance after training, a significant increase in MMP (p = 0.02) estimated by the VDT was observed, as well as a reduction in VTD execution time (p<0.0001).

Handgrip strength obtained by the dynamometer significantly increased after training (p<0.001), and the same could be observed in muscle strength assessed on the six devices (p<0.0001 for all) (Table 2). On the leg press machine, the increase was 158%, followed by 116% in the leg curl and 165% in the leg extension chair. For UL, the increase was 102% on the rowing, 115% on the bench press and 69% on the lat pull down.

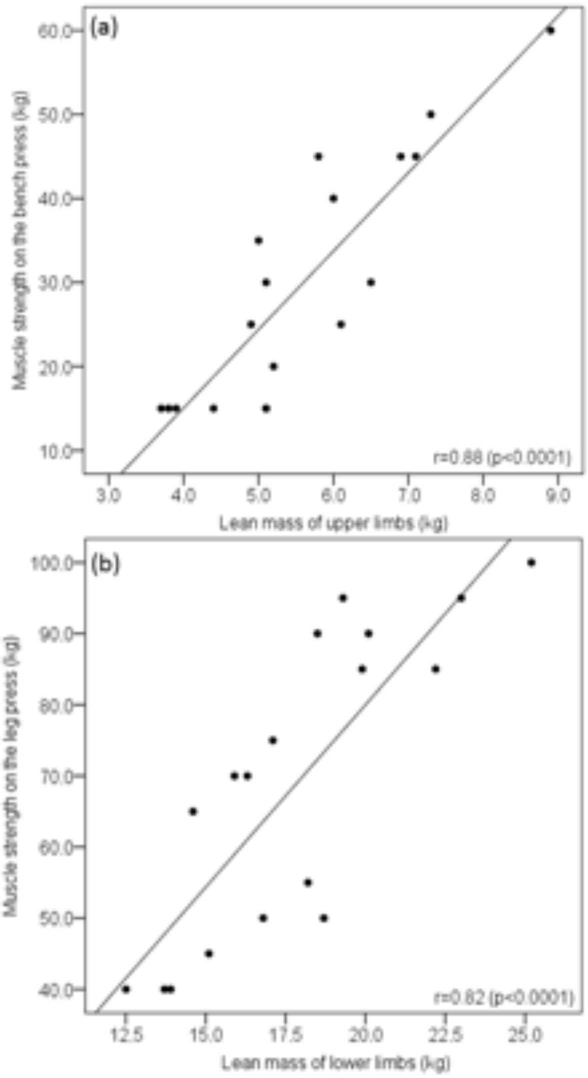
Table 2: Muscle strength and functional performance pre- and post-training.

VARIABLES	PRE-TRAINING	POST-TRAINING
Muscle strength		
Leg press (Kg)	26.67 ± 10.15	68.89 ± 21.39*
Leg extension chair (Kg)	20.55 ±10.83	54.44 ± 19.77*
Leg curl (Kg)	20.83 ± 4.96	45.00 ± 12.00*
Bench press (Kg)	13.89 ±	30.00 ± 14.55*
Rowing (Kg)	14.72 ± 6.29	28.06 ± 9.42*
Lat pull down (Kg)	18.89 ± 7.39	31.94 ± 12.14*
Hand Grip(Kgf)	30.28 ± 7.55	36.00 ± 8.86*
MMP (watts)	297.87 ± 56.00	371.86 ±69.04
VDT Time (seg)	4.46 ± 0.70	3.28 ± 0.50*

Data expressed as mean ± standard deviation. MMP: Maximum muscle power; VDT: vertical displacement test. *p<0.0001 and #p=0.027 comparisons pre- and post-training, via paired Student's t-test.

Correlation analysis between strength and LM of UL and LL at the end of training showed high and significant correlations (r> 0.80, p<0.0001) (Figure 2).

Figure 2. Correlation graphs of (a) strength on the bench press machine and lean mass of the upper limbs; (B) muscle strength on the leg press machine and lean mass of the lower limbs.



DISCUSSION

Bariatric surgery has lessened the impact of obesity on cardiopulmonary and orthopedic complications, however, early and effective interventions in the PO period are needed to mitigate the side effects acquired with the massive reduction of weight, such as the decrease of LM and muscle strength[2,22].

The practice of physical exercises in the PO period with the purpose of maintaining LM and weight loss has been fairly widespread[3-5,15,23,24], however, there seems to be no consensus in literature of what would be the ideal exercise protocol in order to minimize the common muscle changes at this stage. Thus, this study becomes a pioneer in proposing a combined supervised exercise protocol for 36 weeks for intervention in the obese population in the PO bariatric surgery period.

Implementation of the combined program of muscle hypertrophy and aerobic exercise for 36 weeks allowed substantial gains in overall and localized muscle strength in all implemented tests (Table 2), and improved the performance in situations where speed and functionality is required.

It is believed that the prescription of muscular hypertrophy exercises with intensity between 67 and 85% of 1MR of 6 to 12 exercises per session for 2-3 days/week is beneficial to maximize muscle gain[17]. It is assumed that the protocol used in this study has stimulated skeletal muscle to synthesize new muscle proteins, producing hypertrophy and consequently muscle strength gain. Moreover, muscle hypertrophy when initially prioritized also ensures increments of muscular strength and endurance, being very important for a population with a history of physical inactivity and being subjected to rapid and drastic body mass reduction.

Muscle hypertrophy exercise training presents an overall response increase in muscle tone, which can be due to the increase in contractile myofibrils, increasing the cross sectional area. These structural changes give the muscle greater potential for producing maximum force[25].

Strong correlations between LM in LL and post-training muscle strength (leg press) and LM (kg) in UL and post-training muscle strength (bench press) (r=0.88, and r=0.82 respectively, p<0.0001) indicate that for a significant increase in muscle strength to be shown, an increase in muscle mass (size and volume) of the muscles responsible for the increase in strength is also expected. The performance of exocentric exercises promotes a potent stimulus for functional hypertrophy leading to increased muscle mass and strength[18,26,27]. Muscle adaptations resulting from muscle hypertrophy training probably increase body metabolism, and thus induce beneficial changes in muscle function and prepare the muscle structure to support acute and intermittent mechanical overloads that constantly occur in everyday life of an individual, without any osteoarticular losses[27].

The 12% increase evaluated by the handgrip test between the pre- and post-training periods is significant, and from the clinical point of view it could facilitate performing and executing daily living and instrumental activities. Evaluation of muscle grip strength is widely used in clinical practice to infer the muscle strength of individuals, considered as being predictive for various functional outcomes in the area of aging and orthopedic outcomes related to muscle strength, especially in relation to upper limb injuries[21]. Despite the evaluated obese not being elderly nor presenting associated lesions, the purpose of using this instrument was rating and monitoring overall muscle strength, especially that obtained in the UL after the proposed training period.

The significant 25% increase in MMP obtained after training indicates that the weight reduction associated with muscle mass promotes functional increments that make these individuals more agile and more functionally active. The reduction of 16.5% in the vertical displacement test execution time more accurately demonstrates this agility and indicates that this individual is more prepared to deal with common situations in everyday life such as running to catch a bus or start and change the direction of the body quickly and in a controlled manner.

Changes in body composition resulting from weight reduction (reduction of FM% and increased LM%) are already known in the literature and alone they are enough to reduce cardiovascular and osteoarticular risk in the obese[28]. Maximum strength gains and hypertrophy observed after the implemented training were very expressive and may be associated with adaptations such as increased muscle capillarity[29].

LM reduction (2.7 Kg or 5.7%) observed after the study period are in agreement with other studies[28,14,3] which evaluated this variable in the bariatric PO period, and it can be attributed to the adopted surgical procedure. The restrictive component of the surgery can lead to a reduction in the volume of ingested nutrients, mainly proteins that are essential for construction and maintenance of LM; on the other hand, the unabsorbed component is related to poor food absorption disorders leading to calcium and vitamin D deficiencies, which directly interfere in muscle mass[29,30]. The results suggest that the proposed training may have attenuated the observed reductions in LM, since the strength gains were quite evident and demonstrated significant increases in functionality.

The heterogeneity of studies published on exercise in PO bariatric surgery with general unspecific information[3] make it difficult to analyze and compare them with the protocol used in this study to evaluate LM gain and functionality. Coen et al. (2015)[10] followed a semi-supervised program of aerobic exercises such as walking (120 min/week for 12 weeks) that began 80 days after PO and observed improved insulin sensitivity and glucose tolerance compared to control group. Most studies mainly evaluated the effect of walking (more than 150 min/week), helping to reduce weight, improving the quality of life and demonstrating the benefits of keeping active in relation to individuals who remained sedentary[3].

This study has some limitations such as a sample consisting predominantly of women and the fact that their diets were not controlled during the training period, which can directly interfere in muscle mass changes. In addition, randomized controlled clinical trials are essential to confirm the results of this study. New studies are needed to more accurately quantify muscular strength gains and evaluate the impact of this type of training on the quality of life of this population.

CONCLUSION

The results suggest that training with muscle hypertrophy and aerobic exercises promoted significant increases in overall and localized muscle strength, improved functional performance and helped ensure mitigation of LM loss which is so common in the PO period of this surgery. Controlled clinical trials are necessary in order to confirm the findings of this study.

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