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ORIGINAL CONTRIBUTIONS

Impact of Exercise on Body Composition and Cardiometabolic Risk Factors in Patients Awaiting Bariatric Surgery

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Abstract

Background The role of exercise to achieve weight reductions in patients awaiting bariatric surgery has been little studied. The aim of this study was to describe the effects of an exercise program on body composition and cardiometabolic risk factors in patients awaiting bariatric surgery.

Methods Twenty-three patients awaiting bariatric surgery were divided into two groups: (a) an exercise group (EG, $n = 12$) and (b) a control group (CG, $n = 11$). Both groups received the usual care prior to surgery, but the EG also performed a 12-week exercise program which combined endurance and resistance training. Body composition, cardiometabolic risk factors, physical fitness, basal metabolic rate, and quality of life were assessed at baseline and at the end of the study.

Results After the exercise program, the EG achieved significant reductions in total weight (-7.3 ± 4.1 kg, $P < 0.01$), fat mass (-7.1 ± 4.7 kg, $P < 0.01$), and waist circumference (-5.3 ± 2.1 cm, $P < 0.01$), while they maintained their fat-free mass and basal metabolic rate levels. Only the EG showed reductions in HbA1c ($-0.4 \pm 0.45\%$, $P < 0.05$), systolic (-10.5 ± 12.7 mmHg), and diastolic blood pressure (-3.9 ± 5.2 mmHg, $P < 0.05$), as well as a decrease in waist-to-height ratio (-0.032 ± 0.12, $P < 0.01$) and an improvement in quality of life.

Conclusions The implementation of an exercise program prior to bariatric surgery reduces fat mass and central obesity and improves cardiometabolic risk factors and quality of life, especially in the physical scales.

Trial registration The study was registered at ClinicalTrials.gov (NCT03613766).

Keywords Body composition · Cardiometabolic risk · HIIT · Morbid obesity · Prehabilitation · Visceral fat

Introduction

Patients awaiting bariatric surgery (BS) have a large number of comorbidities, such as diabetes, dyslipidemia, or hypertension, which, together with a higher preoperative weight, are associated with a major surgical risk, greater postoperative complications, and a greater mortality rate [1, 2]. Furthermore, bariatric patients normally present liver steatosis and hepatomegaly, mainly of the left hepatic lobe, and high levels of intra-abdominal and visceral fat, which can make the surgery difficult [3, 4].

Preoperative weight loss reduces cardiometabolic risk factors, hepatic volume, fatty content in the liver, and visceral adipose tissue [5]. Altogether, it results in a decreased operation time, a reduced number of intraoperative and postoperative complications, and a shorter hospital stay [6]. Low- or very low–calorie diets are used to achieve preoperative weight loss [4]. Unfortunately, these types of diets in patients awaiting BS also reduce the fat-free mass (FFM) [7], which can lead to lower functional capacity, a reduced basal metabolic rate, and an increase in insulin resistance [8]. In addition, after BS, there is a great loss of FFM [9], so it is important to avoid the loss of FFM before BS.

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On the other hand, low cardiorespiratory fitness also increases the risk of short-term postoperative complications [10]. Therefore, exercise can generate certain benefits in patients awaiting BS. First, the addition of exercise to a low-calorie diet produces greater weight and fat mass losses than diet alone, as resistance training helps reduce the loss of fat-free mass [11]. Secondly, endurance training causes reductions in the liver and visceral fat and increases cardiorespiratory fitness [12]. In this regard, high-intensity interval training (HIIT) can be especially effective, increasing the maximal oxygen uptake and reducing waist circumference and comorbidities in patients affected by obesity [13, 14].

Despite these potential benefits of exercise in patients awaiting BS, currently, there is no consensus about the exercise that should be used by these patients, possibly due to the scarce number of investigations. Some scientific societies recommend performing 20 min of exercise per day, 3–4 days a week [15]. However, neither the progressions nor the appropriate volumes and intensities for each type of exercise have been totally defined. Therefore, the exercise guidelines in these patients have yet to be determined. Consequently, this study aimed to describe the effects of a supervised exercise program that combines endurance and resistance training at high intensities on body composition and cardiometabolic risk factors in patients awaiting BS. Other secondary aims included determining the changes that this exercise program might produce in basal metabolic rate and in the quality of life of these patients.

Materials and Methods

Participants

Patients from two different hospitals from the same city (≈ 230,000 inhabitants) were referred by their corresponding surgical teams to join our research project. Inclusion criteria were to have a body mass index (BMI) ≥ 40 kg m^{-2} or a BMI ≥ 35 kg m^{-2} associated with obesity-related comorbidities. Exclusion criteria were as follows: (a) cardiovascular diseases; (b) severe functional limitations; (c) chronic respiratory diseases; or (d) plans to undergo another exercise program during the period of the study. The investigators did not participate in the initial selection of patients nor did the surgical teams participate in the allocation of the patients in the experimental or control groups. For organizational purposes, given the long duration of the planned exercise intervention, the first patients that arrived at our center were included in the experimental group, independently of the hospital from which they were referred to us, their sex, BMI, etc.

Finally, twenty-three participants (82% of women) were diachronically enrolled in the intervention at 3 to 6 months before the expected date of surgery: the first 12 patients (75% women) were included in the exercise group (EG) and the other 11 patients (90% women) in the control group (CG). There was no interaction between the participants of each group. According to data from previous research [16, 17], we estimated that a minimum sample size of 6 patients per group was required to find differences in the absolute weight change among both groups, with an 80% power and a significance level of 0.01.

The study protocol was approved by the local ethics committee and conformed to the Declaration of Helsinki. A written informed consent was obtained before including the patients in the study. The study was registered at ClinicalTrials.gov (NCT03613766).

Design

A prospective non-randomized study was performed. Both groups followed the usual presurgical care of their respective hospitals (psychological and nutritional counseling). In addition, the EG performed a 12-week monitored and supervised exercise program, while the CG only received advice to follow an active lifestyle. Both groups were evaluated at the start and the end of the study, after 12 weeks. Body composition, anthropometric measures, physical fitness, cardiometabolic risk factors, basal metabolic rate, and health-related quality of life were measured in a laboratory under controlled conditions (temperature 22–24 °C; relative air humidity 45–60%). Blood samples from each patient were obtained at the same time points.

Exercise Program

The exercise program was divided into three 4-week blocks, for a total duration of 12 weeks (Table 1). In the first-block endurance (performed on a cycle ergometer, arm ergometer, elliptical, and treadmill) and resistance training (performed in resistance machines for 5 muscle groups: hamstrings, pectorals, quadriceps, latissimus dorsi, and gastrocnemius) were combined in the same session and performed twice a week. During the second-block, patients performed 3 sessions per week. One day, the patients only performed endurance training. In the other 2 sessions, patients performed a HIIT on a cycle ergometer or an arm ergometer followed by 7 resistance exercises (biceps and triceps brachii were added to the previous 5 major muscle groups trained).

In the third-block, patients trained 4 days a week. Two days a week, HIIT and resistance training were combined in the same session. Resistance training was performed after HIIT. It consisted in training 4 different major muscle groups in each session (pectorals, quadriceps, biceps, and hamstrings in the first session, and latissimus dorsi, triceps, gastrocnemius, and deltoids in the second session). In the other two sessions, the

Table 1 Exercise program performed by the experimental group

	Block 1	Block 2	Block 3
Sessions per week	2	3	4
Resistance training	- 2 d/w - 1 set - 5 exercises - 20 repetitions - ~ 50% RM	- 2 d/w - 1 set - 7 exercises - 20 repetitions - ~ 60% RM	- 2 d/w - 4 sets - 4 exercises - 15 repetitions - ~ 65% RM
Endurance training	- 2 d/w 35′ ET (60–70% HR_{max})	- 2 d/w HIIT (60–70% VO_{2peak}) - 1 d/w ET 50′ (70–75% HR_{max})	- 2 d/w HIIT (70–80% VO_{2peak}) - 2 d/w ET 50′ (70–80% HR_{max})
Stretching training	- 2 d/w - 4 exercise - 1′ for exercise	- 2 d/w - 4 exercise - 1′ for exercise	- 2 d/w - 4 exercise - 1′ for exercise

d/w indicates day per week; *RM*, repetition maximum; *ET*, endurance training; HR_{max}, maximal heart rate; *HIIT*, high-intensity interval training; VO_{2peak}, peak oxygen uptake

patients only performed endurance training. In all the blocks, flexibility training was performed twice a week.

The intensity of the endurance training was monitored using a heart rate monitor (FT40, Polar, Finland), while the intensity of the resistance training was determined by percentages of 1 maximum repetition, which was estimated using the Brzycki formula [18].

The HIIT performed consisted of a 5-min warm-up, followed by the main part of 20 min with bouts of 30 s at a high intensity (60–80% VO_{2peak}) and 30 s of active recovery (40% VO_{2peak}), for a total of 10 min of training at high intensity. Once the main part was finished, there was 3 min of cool-down at 40% VO_{2peak}.

The rate of perceived exertion was taken of each session using the CR-10 Borg's scale in order to control the progression of training loads [19].

Test Measures

Anthropometry and Body Composition

These measures were performed between 7:30 and 8:30 A.M., after a 10–12-h fasting period, with an empty bladder [20]. Exercise was forbidden in the 72 h before the test, as well as the consumption of caffeine or alcohol in the 24 h before the test. Waist and hip circumference and height were measured using the ISAK (International Society for the Advancement of Kinanthropometry) protocol [21]. Total weight and body composition were measured by bioimpedance analysis (Tanita BC-420MA, Tanita, Tokyo, Japan). BMI was calculated and expressed as kg m^{-2} [22]. The excess weight loss (%EWL) was calculated with the formula: %EWL = (initial weight − current weight) / (actual weight − ($25 \times height^2$)) × 100) [23].

Basal Metabolic Rate

Basal metabolic rate was calculated by indirect calorimetry, using an Oxycon Pro gas analysis system (Jaeger, Friedberg, Germany). The patients rested for 30 min in a supine position in a comfortable bed. To perform the analysis, only the data from the last 10 min of the assessment were used. Basal metabolic rate was determined according to the Weir formula [24], and it was measured at the same time of the day and under the same ambient conditions as the anthropometry and body composition measurements.

Cardiometabolic Risk Factors

Blood samples were obtained after 12-h overnight fasting. Patients were instructed not to perform exercise 48 h before the test. Standard methods were used to measure total cholesterol, HDL cholesterol, glucose, glycated hemoglobin (HbA1C), and triglycerides. Friedwald equation was used for calculating LDL cholesterol [25]. Blood pressure was measured according to established recommendations [26], using a digital sphygmomanometer (Microlife WatchBP Home, Heerbrugg, Switzerland). Furthermore, cardiovascular risk was also determined by the waist-to-height ratio [27].

Cardiorespiratory Fitness

A protocol in cycle ergometer (Technogym Bike Med, Technogym, Gambettola, Italy) adapted from Achten [28] was used to determine the peak oxygen uptake (VO_{2peak}). Gas analyses were performed using an Oxycon Pro gas analysis system (Jaeger, Friedberg, Alemania). The protocol consisted of two phases. In the first phase, patients performed a 4-min warm-up at 40 W (W), followed by increases of 20 W every 3 min, maintaining a cadence of 60 rotations per minute

Table 2 Baseline characteristics of participants

	Total ($n = 18$)	EG ($n = 10$)	CG ($n = 8$)
Age (years)	40.3 ± 8.01	42.5 ± 5.1	37.5 ± 10.3
Weight (kg)	126.6 ± 29.74	137.2 ± 36.5	113.33 ± 8.8
BMI (kg m^{-2})	45.9 ± 9.2*	47.5 ± 7.1	41.5 ± 2.7
Fat mass (%)	50.1 ± 3.1	49.5 ± 3.4	50.8 ± 2.7
Fat-free mass (kg)	63.2 ± 16.1	69.3 ± 19.7	55.6 ± 3.1
Relative VO_{2peak} (mL kg^{-1} min^{-1})	15.9 ± 4.81	16.0 ± 5.1	15.8 ± 1.2
Absolute VO_{2peak} (L min^{-1})	1.9 ± .48	2.1 ± .63	1.8 ± .22
Type-2 diabetes (%)	27.8	40.0	12.5
Current smoker (%)	16.7	30.0	00.0
Female (%)	83.3	70.0	100.0

Data are mean ± SD; *EG*, exercise group; *CG*, control group; *BMI*, body mass index; VO_{2peak}, peak oxygen uptake

Note: * Inter-group differences ($P < 0.05$)

(RPM), until the respiratory exchange ratio reached 1.0. At this point, the second phase started, which consisted of increments of 20 W per minute, maintaining a cadence between 70 and 80 RPM, until volitional fatigue. The average of the highest 30 s of VO_2 was used to calculate VO_{2peak}. The VO_{2peak} was expressed in absolute values (L min^{-1}) and relativized to the total weight (mL kg^{-1} min^{-1}). Subjects that had leg musculoskeletal disorders performed the same test in an arm ergometer but initiated at 20 W with increases of 10 W (Technogym, Excite®+Top MD Inclusive).

Muscle Strength

Dynamic and isometric strength of the quadriceps, hamstrings, biceps, and triceps brachii were assessed using an isokinetic dynamometer (Biodex System 4; Biodex Medical Systems, NY, USA). First, patients performed a 5-min warm-up on a cycle ergometer at an intensity of 60% of individual maximum heart rate. Next, participants were stabilized on the dynamometer chair (seat back angle ~ 85°) with two shoulder straps and a thigh strap. The anatomical axis of rotation was aligned to the dynamometer axis to allow movement in the sagittal plane for the knee and in the transversal plane for the elbow. For each limb, 3 unipodal tests were performed, 1 isokinetic test and 2 isometric tests. A 2-min rest was conducted between tests and a 3 min rest between limbs.

Maximal Dynamic Strength Participants performed 4 sets of 4 concentric contractions (flexion-extension) of the upper (elbow) and lower body (knee), at an angular speed of 60° s^{-1}, with 90-s rest between repetitions. The knee and elbow motion ranges were within 105° to 10° and within 160° to 60°, respectively. The first series was a submaximal familiarization trial. In the following three sets, participants were verbally encouraged to perform and maintain maximal effort in every contraction. The peak torque (N m) of each set was analyzed and the average of the last three sets was calculated. Additionally, the peak torque was relativized to the individual's body weight (N m kg^{-1}·100).

Maximal Isometric Strength Participants completed a submaximal repetition followed by 3 maximum voluntary contractions (15-s rest between repetitions), during which they were verbally encouraged to perform at maximal effort for 5 s, following the recommendations of previous research [29]. The angles used for assessing quadriceps and hamstrings were of 105° and 75°, respectively, and triceps and biceps brachii were of 75° and 120°, respectively. As there was one set per exercise, the peak torque (N m) was analyzed and relativized to the body weight (N m kg^{-1}·100).

Health-Related Quality of Life

The Short Form Health Survey 36 (SF-36) in its version adapted to the Spanish context [30] was used to determine health-related quality of life of the patients. Physical and mental health were measured by 8 scales, and the scores of which were transformed to values between 0 and 100 points, the highest scores indicating a better function. These 8 scales were grouped into two summary components (physical and mental), which were calculated according to the reference values of the Spanish population [31], with a mean of 50 and a standard deviation of 10.

Statistical Analysis

Statistical analysis was conducted using the statistical package SPSS 22.0 (SPSS Inc., Chicago, IL, USA). The normality of the variables was verified by the Kolmogorov-Smirnov test. Inter-group and intra-group differences were analyzed by one-way ANOVA, paired *t* test or Wilcoxon paired test. ANCOVA was used to exclude the effect of differences in the

anthropometric variables at the beginning of the intervention on its results. Pearson's bivariate correlation was used to analyze associations between cardiovascular risk variables, body composition, anthropometric measures, and physical fitness. Significant differences were considered when $P < 0.05$. Cohen's d was used to calculate effect sizes and interpreted as d 0.20–0.50 (small), 0.50–0.80 (medium), and > 0.80 (large) [32]. Unless otherwise indicated, data are presented as mean ± standard deviation, with its corresponding 95% confidence interval (95% CI).

Results

Program Completion

Two women of the EG did not finish the exercise program (one left the program and another experienced physical problems). In the CG, 3 subjects (two women and one man) dropped out of the study. Finally, 18 patients completed the study (Table 2). Patients from different hospitals did not show significant differences among them in the variables evaluated. Patients of hospital-1 ($n = 13$; 8 patients in EG) reported a mean age of 41.7 ± 7.6 years and an initial BMI of 45.2 ± 7.1 kg m^{-2}. Patients of hospital-2 ($n = 5$; 2 patients in EG) had a mean age of 36.6 ± 8.8 years and an initial BMI of 44.0 ± kg m^{-2} ± 3.6.

Body Composition, Anthropometry, and Basal Metabolic Rate

After the exercise program, the EG obtained significant reductions in all anthropometric and body composition variables evaluated except in the FFM, which remained constant. All these variables, excluding FFM, showed significant differences between groups (Table 3). The EG had significantly greater reductions than the CG in the percentage of BMI reduction (− 5.6 ± 3.32% vs − 0.57 ± 1.95%, $P = 0.002$), fat mass (− 10.93 ± 7.73 vs − 1.75 ± 3.05%, $P = 0.005$), and visceral fat (− 11.28 ± 7.49% vs − 2.33 ± 5.20%, $P = 0.011$). The ANCOVA showed that the absolute changes of the anthropometric variables in response to exercise in the EG were independent of the initial BMI (change in (a) weight, $P = 0.100$; (b) BMI, $P = 0.663$; (c) FM, $P = 0.957$; (d) FFM, $P = 0.284$; (e) visceral fat: $P = 0.218$; (f) waist-to-hip ratio, $P = 0.912$). Additionally, by the end of the intervention, the %EWL was of 15.2 ± 11.2% vs. 1.5 ± 5.2% in the EG and the CG, respectively ($P = 0.006$; 95% CI, 4.6–22.8; Student's t test). Significant changes in the basal metabolic rate were not observed in any of the groups (Table 3).

Table 3 Changes in body composition, anthropometric data, and basal metabolic rate after the intervention

	Group	Test 1	Test 2	Intra-group differences (P value)	Absolute change (T2-T1)	Inter-group differences (P value)
Weight (kg)	EG	137.2 ± 36.5	130.0 ± 37.0	*0.005*	− 7.3 ± 4.1 (− 10.2, − 4.34)	*0.001*
	CG	113.3 ± 8.8	112.7 ± 9.3	0.450	− 0.62 ± 2.2 (− 2.5, 1.2)	
BMI (kg m^{-2})	EG	47.5 ± 7.1	44.9 ± 7.5	*0.000*	− 2.6 ± 1.5 (− 3.6, − 1.5)	*0.001*
	CG	41.5 ± 2.7	41.3 ± 2.6	0.421	− 0.25 ± 0.83 (0.94, 0.44)	
FM (kg)	EG	67.9 ± 17.8	60.8 ± 18.7	*0.001*	− 7.1 ± 4.7 (− 10.4, − 3.7)	*0.004*
	CG	57.7 ± 6.9	56.6 ± 6.5	0.140	− 1.1 ± 1.8 (− 2.6, 0.45)	
FM (%)	EG	49.5 ± 3.4	46.7 ± 4.7	*0.005*	− 2.8 ± 2.4 (− 4.5, − 1.1)	*0.033*
	CG	50.8 ± 2.7	50.2 ± 2.4	0.175	− 0.62 ± 1.8 (− 1.6, 0.35)	
FFM (kg)	EG	69.3 ± 19.7	69.1 ± 20.2	0.657	− 0.20 ± 1.4 (− 1.2, 0.78)	0.380
	CG	55.6 ± 3.0	56.0 ± 3.9	0.472	0.44 ± 1.6 (− 0.93, 1.8)	
FFM (%)	EG	50.5 ± 3.4	53.3 ± 4.7	*0.005*	2.8 ± 2.4 (1.1, 4.5)	*0.033*
	CG	49.2 ± 2.7	49.8 ± 2.4	0.175	0.62 ± 1.8 (− 0.35, 1.6)	
Waist (cm)	EG	133.6 ± 17.6	128.3 ± 17.2	*0.000*	− 5.3 ± 2.1 (− 6.9, 3.8)	*0.006*
	CG	118.2 ± 6.7	116.6 ± 6.9	0.165	− 1.6 ± 2.9 (− 4.1, 0.84)	
Hip (cm)	EG	143.9 ± 19.6	139.0 ± 19.5	*0.002*	− 5.0 ± 3.7 (− 7.6, − 2.3)	*0.006*
	CG	136.2 ± 8.5	135.6 ± 8.9	0.162	− 0.65 ± 1.2 (− 1.6, 3.3)	
Visceral fat	EG	22.5 ± 8.7	20.0 ± 8.3	*0.002*	− 2.5 ± 1.9 (− 3.9, − 1.1)	*0.009*
	CG	14.00 ± 1.5	13.6 ± 1.5	0.197	− 0.37 ± 0.74 (− 1.0, 0.25)	
BMR (Kcal day^{-1})	EG	2329.3 ± 425.7	2235.2 ± 509.9	0.392	− 94.1 ± 331.2 (− 331.1, 142.8)	0.665
	CG	1908.2 ± 297.7	1870.83 ± 274.4	0.438	− 37.4 ± 128.6 (− 144.9, 70.1)	

Data are mean ± SD. 95% confidence intervals in brackets

EG, exercise group; *CG*, control group; *BMI*, body mass index; *FM*, fat mass; *FFM*, fat-free mass; *BMR*, basal metabolic rate

Table 4 Changes in cardiometabolic risk factors after the intervention

	Group	Test 1	Test 2	Intra-group differences (*P* value)	Absolute change	Inter-group differences (*P* value)
Glucose (mg dL^{-1})	EG	119.7 ± 44.3	102.5 ± 19.4	0.074	− 17.7 ± 25.7 (− 37.5, 2.1)	0.226
	CG	96.7 ± 17.9	93.3 ± 12.5	0.506	− 3.3 ± 11.4 (− 15.3, 8.6)	
TC (mg dL^{-1})	EG	178.1 ± 21.7	188.2 ± 29.9	0.567	10.1 ± 47.6 (− 29.7, 50.0)	0.687
	CG	166.3 ± 23.2	168.7 ± 30.3	0.643	2.4 ± 13.2 (− 9.7, 14.6)	
LDL-C (mg dL^{-1})	EG	107.4 ± 23.3	112.9 ± 27.4	0.724	5.5 ± 42.3 (− 29.9, 40.9)	0.944
	CG	89.7 ± 17.2	94.0 ± 19.7	0.466	4.3 ± 14.6 (− 9.2, 17.7)	
HDL-C (mg dL^{-1})	EG	43.6 ± 6.9	48.6 ± 11.4	0.092	5.0 ± 7.2 (− 1.1, 11.1)	*0.036*
	CG	55.0 ± 20.5	52.1 ± 16.7	0.218	− 2.9 ± 5.5 (− 7.9, 2.2)	
TG (mg dL^{-1})	EG	135.9 ± 34.3	134.4 ± 52.7	0.920	− 1.5 ± 40.8 (− 35.7, 32.6)	0.746
	CG	121.7 ± 49.5	113.3 ± 58.6	0.597	− 8.4 ± 39.9 (− 45.4, 28.5)	
HbA1C (%)	EG	6.2 ± 1.29	5.8 ± 1.12	*0.018*	− 0.4 ± 0.45 (− 0.77, − 0.02)	0.353
	CG	5.98 ± .86	5.78 ± .61	0.119	0.2 ± 0.36 (− 0.47, 0.07)	
SBP (mmHg)	EG	138.4 ± 21.9	127.8 ± 19.7	*0.015*	− 10.5 ± 12.7 (− 19.6, 1.4)	*0.009*
	CG	126.2 ± 22.3	130.1 ± 24.5	0.110	3.9 ± 6.2 (− 1.1, 9.0)	
DBP (mmHg)	EG	83.2 ± 10.6	79.3 ± 9.7	*0.039*	− 3.9 ± 5.2 (− 7.6, − 2.4)	0.167
	CG	77.2 ± 7.87	76.8 ± 9.4	0.811	− 0.43 ± 5.0 (− 4.6, 3.7)	
WHtR	EG	0.790 ± 0.068	0.758 ± 0.068	*0.000*	− 0.032 ± 0.12 (− 0.02, 0.1)	*0.007*
	CG	0.716 ± 0.047	0.706 ± 0.046	0.159	− 0.01 ± 0.018 (− 0.02, 0.005)	

Data are mean ± SD. 95% confidence intervals in brackets

EG, exercise group; *CG*, control group; *TC*, total cholesterol; *LDL-C*, *LDL*, cholesterol; *HDL-C*, HDL cholesterol; *HbA1C*, glycosylated hemoglobin; *SBP*, systolic blood pressure; *DBP*, diastolic blood pressure; *WHtR*, waist-to-height ratio

Cardiometabolic Risk Factors

In the CG, no significant changes were observed in any of the evaluated variables. However, in the EG, there were significant reductions in HbA1C levels ($P = 0.040$; $d = 0.33$; 95% CI, − 0.78, − 0.02) and in systolic ($P = 0.028$; $d = 0.51$; 95% CI, − 19.6, − 1.5) and diastolic blood pressure ($P = 0.039$; $d = 0.39$; 95% CI, − 7.6, − 0.24) following the exercise program. In addition, there were moderate reductions in glucose levels ($P = 0.074$; $d = 0.52$; 95% CI, − 37.5, 2.1), and moderate increases in HDL cholesterol levels ($P = 0.092$; $d = 0.53$; 95% CI, − 1.1, 11.1). Waist-to-height ratio only decreased significantly in the EG. After the intervention, absolute changes in HDL cholesterol, systolic blood pressure, and waist-to-height ratio showed significant differences between groups (Table 4).

Cardiorespiratory Fitness and Muscle Strength

There were no significant differences between groups in the physical fitness variables (Table 5). However, the EG showed significant improvements in peak oxygen uptake relative to body weight ($P = 0.004$, 95% CI, 0.98, 3.5), with a large change compared to the CG ($d = 0.85$). In the EG, isometric strength showed a tendency to increase in the lower body, but only significant increases were obtained in the maximal isometric strength relativized to body weight for the hamstrings (right hamstring: $P = 0.007$, 95% CI, 4.0, 16.8; left hamstring: $P = 0.049$, 95% CI, 0.02, 14.7).

Regarding the dynamic strength, the EG showed significant increases of hamstring in the maximal dynamic strength (right hamstring, $P = 0.012$, 95% CI, 3.9, 21.7; left hamstring, $P = 0.040$, 95% CI, 0.33, 10.7) and in hamstrings and left quadriceps in maximal dynamic strength relativized to body weight (right hamstring, $P = 0.002$, 95% CI, 7.3, 20.7; left hamstring, $P = 0.002$, 95% CI, 3.7, 11.2; left quadriceps, $P = 0.005$, 95% CI, 3.0, 11.2). In the upper body, only the CG showed significant improvements, specifically in the right biceps in maximal dynamic strength ($P = 0.010$, 95% CI, 1.4, 6.8) and in maximal dynamic strength normalized to body weight ($P = 0.011$, 95% CI, 1.2, 6.4).

Health-Related Quality of Life

After the exercise program, the EG increased their scores on all scales of the SF-36. These increases were significant in 3 of the 8 scales of the questionnaire (physical functioning, $P = 0.002$, 95% CI, 11.7, 39.2; general health perceptions, $P = 0.003$, 95% CI, 8.0, 27.6; mental health, $P = 0.021$, 95% CI, 1.9, 18.8), and in one of the scales, social functioning, there was a large increase ($d = 0.81$, 95% CI, − 0.13, 1.68). In addition, the EG also showed a significant increase in the physical component summary ($P = 0.004$, 95% CI, 3.1, 12.3). The CG

Table 5 Changes in physical fitness after the intervention

	Group	Test 1	Test 2	Intra-group differences (*P* value)	Absolute change	Inter-group differences (*P* value)
Absolute VO_{2peak} (L min^{-1})	EG	2.08 ± 0.63	2.22 ± 0.56	0.125	0.14 ± 0.25 (− 0.06, 0.34)	0.599
	CG	1.8 ± 0.22	1.86 ± 0.26	0.366	0.076 ± 0.23 (− 0.11, 0.26)	
Relative VO_{2peak} (mL kg^{-1} min^{-1})	EG	16.0 ± 5.1	18.2 ± 5.2 [b]	*0.004*	2.2 ± 1.47 (0.98, 3.5)	0.111
	CG	15.8 ± 1.2	16.5 ± 1.9	0.295	0.76 ± 1.9 (− 0.83, 2.4)	
MDS right quadriceps (N m)	EG	156.5 ± 54.2	153.6 ± 47.0	0.664	2.8 ± 16.5 (− 18.1, 12.4)	0.534
	CG	141.5 ± 31.8	144.0 ± 37.6	0.668	2.5 ± 14.9 (− 2.3, 4.3)	
MDS_{BW} right quadriceps (N m kg^{-1} 100)	EG	115.5 ± 24.6	122.4 ± 23.1	0.120	6.9 ± 10.1 (− 2.4, 16.2)	0.468
	CG	123.8 ± 26.6	126.2 ± 30.2	0.615	2.4 ± 12.2 (− 8.8, 13.7)	
MIS right quadriceps (N m)	EG	151.5 ± 49.4	159.1 ± 71.8	0.484	7.7 ± 29.1 (− 17.7, 32.0)	0.333
	CG	134.3 ± 24.0	129.7 ± 21.5	0.428	4.6 ± 14.4 (− 17.9, 8.7)	
MIS_{BW} right quadriceps (N m kg^{-1} 100)	EG	112.5 ± 23.5	123.3 ± 28.2	0.085	10.8 ± 15.3 (− 2.0, 23.6)	0.081
	CG	117.4 ± 19.3	114.2 ± 19.1	0.547	3.1 ± 13.0 (− 36.3, 13.8)	

Data are mean ± SD. 95% confidence intervals in brackets. *EG*, exercise group; *CG*, control group; VO_{2peak}, peak oxygen uptake; *MDS*, maximal dynamic strength; MDS_{BW}, maximal dynamic strength relative to body weight; *MIS*, maximal isomeric strength; MIS_{BW}, maximal isometric strength relative to body weight

showed significant increases in physical role ($P = 0.042$, 95% CI, 1.1, 40.6), a small change in bodily pain ($d = 0.43$, 95% CI − 0.75, 1.54) and a moderate change in emotional role ($d = 0.52$, 95% CI − 0.67, 1.63). A significant difference between groups was obtained in absolute changes in physical functioning, general health perceptions, and physical component summary (Table 6).

Discussion

Patients awaiting BS who performed a 3-month exercise program obtained greater reductions in total weight and visceral fat, and greater improvements in cardiometabolic risk factors than patients who only received the usual care. These results are especially important in the clinical setting, as improvements in these variables can reduce the risk of suffering from perioperative complications. Regarding body composition, the reduction of 5.6% of BMI and total weight and the reduction of 11.3% of visceral fat in the EG should be highlighted. This provides several advantages. On the one hand, it has been determined that the total weight loss between 5 and 10% preoperatively may reduce the surgical risk, and it is associated with a shorter operative time and a lower number of complications after surgery [6]. On the other hand, a reduction of 5% of the BMI has been associated with significant decreases in liver steatosis and liver volume in patients with nonalcoholic steatohepatitis [33]. This, together with the reduction of visceral fat achieved through the exercise program, can facilitate the surgical procedure [4]. These results are achieved without a loss of FFM or a reduction in the basal metabolic rate, which can be of great relevance since after surgery, large reductions of these parameters are expected [9]. Furthermore, maintenance of basal metabolic rate could generate greater weight losses than in individuals who have reduced their basal metabolic rate in the preoperative period.

The EG showed reduced HbA1c and blood pressure as well as reduced glucose levels and increased HDL cholesterol. These improvements may reduce the surgical risk, since both, hypertension and diabetes, are associated with postoperative complications and mortality [1, 2]. Possibly, the improvements in the EG are due to a multifactorial component. First, high values of visceral fat, waist circumference, or waist-to-height ratio have been positively associated with HbA1c, glucose, and hypertension and negatively associated with HDL cholesterol [34, 35]. In our study, significant decreases in these cardiometabolic variables were observed in the EG. Therefore, part of the improvements in cardiometabolic risk factors can be attributed to these reductions in anthropometric parameters, together with weight loss. Second, exercise itself

Table 6 Changes in SF-36 scores after the intervention

	Group	Test 1	Test 2	Intra-group differences (*P* value)	Absolute change	Inter-group differences (*P* value)
Physical functioning	EG	57.0 ± 24.8	82.5 ± 12.5	*0.002*	25.5 ± 19.2 (11.7, 39.2)	*0.026*
	CG	60.8 ± 27.1	63.3 ± 27.9	0.707	2.5 ± 15.4 (−13.7, 18.7)	
Role physical	EG	45.0 ± 42.2	52.5 ± 38.1	0.496	7.5 ± 33.4 (−16.4, 31.4)	0.389
	CG	20.8 ± 40.0	41.7 ± 34.2	*0.042*	20.8 ± 18.8 (1.1, 40,6)	
Bodily pain	EG	55.6 ± 31.0	63.6 ± 26.1	0.164	8.0 ± 16.7 (−3.9, 19.9)	0.616
	CG	51.2 ± 29.1	63.5 ± 28.5	0.113	12.3 ± 15.7 (−4.2, 28.8)	
General health perceptions	EG	45.1 ± 20.3	62.9 ± 19.1	*0.003*	17.8 ± 13.7 (8.0, 27.6)	*0.005*
	CG	51.5 ± 28.8	48.2 ± 30.4	0.44	−3.3 ± 9.8 (−13.6, 7.0)	
Vitality	EG	49.5 ± 29.1	56.5 ± 19.1	0.094	7.0 ± 11.8 (−1.5, 15.5)	0.656
	CG	45.8 ± 23.3	50.0 ± 28.1	0.448	4.2 ± 12.4 (−8.9, 17.2)	
Social functioning	EG	77.5 ± 29.3	95.0 ± 8.7	0.066	17.5 ± 26.5 (−1.4, 36.4)	0.159
	CG	79.2 ± 17.1	79.2 ± 23.3	1.000	0.0 ± 13.7 (−14.4, 14.4)	
Role emotional	EG	86.7 ± 32.2	90.0 ± 22.5	0.591	3.3 ± 18.9 (−10.2, 16.9)	0.174
	CG	61.1 ± 44.3	83.3 ± 40.8	0.175	22.2 ± 34.4 (−13.9, 58.3)	
Mental health	EG	76.8 ± 18.2	87.2 ± 7.9	*0.021*	10.4 ± 11.8 (1.9, 18.8)	0.367
	CG	70.0 ± 21.3	74.0 ± 20.5	0.557	4.0 ± 15.6 (−12.4, 20.4)	
Physical component summary	EG	34.9 ± 11.8	42.6 ± 8.3	*0.004*	7.7 ± 6.4 (3.1, 12.3)	*0.046*
	CG	36.0 ± 8.5	37.5 ± 10.3	0.207	1.6 ± 2.6 (−1.2, 4.3)	
Mental component summary	EG	53.1 ± 11.3	54.7 ± 6.4	0.460	1.7 ± 6.8 (−3.2, 6.5)	0.668
	CG	48.1 ± 10.1	51.4 ± 10.4	0.337	3.2 ± 7.5 (−4.6, 11.1)	

Data are mean ± SD. 95% confidence intervals in brackets. *EG*, exercise group; *CG*, control group

reduces cardiometabolic risk factors. For example, both endurance and resistance training trigger the expression and sarcolemmal translocation of the GLUT4 glucose transporter, thus increasing the effects of insulin [36].

Unfortunately, up to now, few studies have evaluated the effects of a supervised exercise program on patients awaiting BS. Most of them show that in interventions lasting between 3 and 6 months, both endurance and resistance training, isolated or combined, show improvements in the total weight and cardiometabolic risk factors [37–39]. For instance, a study in which an exercise program was added to the usual care 4 months before BS showed weight loss in the patients who performed it, while the group that received the usual care showed weight increases [39]. In another study, the group that performed the exercise program had a loss of approximately 5 kg more than the standard care group [40]. Our results are in agreement with these studies with the advantage that, in addition to the total weight, the body composition was evaluated. Therefore, we consider that it would be possible to attribute the weight loss solely to the reduction of fat mass.

In addition, we observed an increase of 2.2 mL kg^{-1} min^{-1} in the peak oxygen uptake in the EG. This result should be highlighted because a low cardiorespiratory capacity is associated with a longer hospital length of stay [10, 41]. Furthermore, patients with a peak oxygen uptake lower than 15.8 mL kg^{-1} min^{-1} or an anaerobic threshold lower than 11 mL kg^{-1} min^{-1} present a higher risk of suffering from postoperative complications [10, 41]. Therefore, increasing cardiorespiratory fitness could also potentially contribute to reducing surgical risk.

As secondary results, we also evaluated the effects of the exercise program on the quality of life. Usually, short-term improvements in quality of life in patients who undergo BS can be observed [42]. However, our study shows similar improvements in the EG, especially of the physical summary component, compared to those obtained through surgery [42]. The exercise program has an important role in these effects since physical activity levels have been associated with better scores of the physical summary component in patients with morbid obesity [43]. Exercise increases physical fitness and functional capacity, which may contribute to the increase of physical scale scores. Besides, the weight loss itself that occurs in the EG also contributes to the improvement of the quality of life [44]. Finally, in our study, the EG reports improvements of the mental scales. This can be due to the group training sessions, in which patients interacted with people who were in the same situation, creating social links. However, in the CG, these improvements are only observed in the physical role, which can be due to the patients were only instructed to walk before the surgery.

This study has several limitations that should be addressed in future works. First of all, the sample size is small, which makes it difficult to generalize results. Secondly, both groups

are not totally comparable, as the EG patients presented a higher BMI, which could have influenced the results. Thirdly, sex ratios were not equally distributed in both groups.

Conclusions

The results of the present study show a short, supervised, and individually prescribed exercise program that combines endurance and resistance training and progressed from low to high intensities generates a series of benefits in patients who are awaiting BS. On the one hand, there is a reduction in weight, maintaining the FFM, and without significant reductions of basal metabolic rate. In addition, there is an improvement of cardiorespiratory fitness and a decrease in the visceral fat, waist circumference, waist-to-height ratio, and cardiometabolic risk factors.

The improvements in these variables can generate great benefits in bariatric patients. First, maintaining the basal metabolic rate could help further weight loss after surgery. Second, several studies show the importance of prehabilitation before major surgery to reduce postoperative complications and reach a faster postoperative recovery [45–47]. Unfortunately, at present, there is little research on this topic in bariatric patients. Therefore, more studies are needed to determine the appropriate intensities and amount of training in this type of patients and to establish the effects that presurgical exercise programs may have on the operation time, hospital length of stay, and short-term postoperative complications.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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