

Article

Effects of a Combined High-Intensity Interval Training and Resistance Training Program in Patients Awaiting Bariatric Surgery: A Pilot Study

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Received: 19 February 2019; Accepted: 21 March 2019; Published: 25 March 2019



Abstract: Bariatric surgery (BS) is considered the most effective treatment for morbid obesity. Preoperative body weight is directly associated with a higher surgical morbimortality and physical activity could be effective in the preparation of patients. The aim of this study is to determine the effects of a six-month exercise training program (ETP), combining high-intensity interval training (HIIT) and resistance training in patients awaiting BS. Six candidates awaiting BS ($38.78 \pm 1.18 \text{ kg}\cdot\text{m}^{-2}$; 38.17 ± 12.06 years) were distributed into two groups: the ETP group (experimental group (EG), $n = 3$) and a control group (CG, $n = 3$). Anthropometrical and blood pressure (BP), cardiorespiratory fitness and maximal strength were registered before and after the ETP. The EG participated in 93.25% of the sessions, showing reductions in body mass index (BMI) compared to the CG (34.61 ± 1.56 vs. 39.75 ± 0.65 , $p = 0.006$, ANOVA). The inferential analysis showed larger effects on BMI, excess body weight percentage and fat mass, in addition to small to moderate effects in BP and the anthropometric measurements. Peak oxygen uptake normalized to fat-free mass showed likely positive effects with a probability of >95–99%. A six-month ETP seems to be a positive tool to improve body composition, cardiometabolic health, and fitness level in patients awaiting BS, but a larger sample size is needed to confirm these findings.

Keywords: morbid obesity; resistance training; HIIT; body composition; cardiometabolic risk

1. Introduction

Obesity is considered a worldwide epidemic, one of the greatest public health problems, and one of the primary death causes, both in the European Union and in the USA [1,2]; likewise, obesity is associated with cardiovascular disease risk factors, some types of cancer, type 2 diabetes mellitus, hypertension, hyperlipidemia, immune response affectation, greater morbidity and mortality state, and a considerable reduction of life expectancy [3,4]. In addition, the increase in the obesity rate and its associated diseases have been related to an increase in the variety of therapeutic interventions [5]. In cases of morbid obesity (body mass index (BMI) $\geq 40 \text{ kg}/\text{m}^2$), bariatric surgery (BS) has been demonstrated to be the most effective treatment for the loss and maintenance of body weight, as well as for the improvement of comorbidities and mortality associated with this pathology [6]. Nevertheless, even though physical activity is recommended to optimize BS results, nowadays the majority of candidates for BS are sedentary and do not increase their physical activity levels after surgery [7].

The influence of physical activity in maintaining long-term weight loss has been known for years, but its role in the preparation of patients awaiting surgery is not well-known. It has been

suggested that it could reduce anesthetic risk and improve postoperative recovery [8]. The higher the preoperative weight is, the higher the risk of morbidity and mortality is. Currently, a low-calorie diet is recommended in short-term preoperative weight loss interventions, as these diets seem to be related to a decrease in the liver size and intraabdominal fat mass which reduce the surgical risk [9]. However, the loss of fat-free mass (FFM) associated with these interventions is an unintended consequence of BS and it is expected to cause a decrease in resting energy expenditure (REE) that could be related to weight regain after surgery [10]. Consequently, it is necessary to implement programs that improve the preoperative conditions and reduce the risk factors in patients awaiting BS. Experimental studies show that exercise training program (ETP) physical activity programs after BS provide benefits for health and fitness level in individuals with morbid obesity [11–13]. Moreover, after a physical activity program lasting six months prior to BS, there were increases in the practice of postoperative physical activity [14]. Other studies in which preoperative ETPs were conducted combining aerobic training with resistance training or only applying aerobic or resistance training have been shown to be effective in improving body weight, physical condition, quality of life related to health, and they also help to improve their willingness to practice physical activity in candidates awaiting BS [3,8,15–19]. However, methodologies to prescribe a training workload are not well-defined in this population.

Several studies have consistently found that high-intensity interval training (HIIT) is useful to increase aerobic capacity and muscle mass, the benefits of which are similar to those obtained with moderate-intensity continuous training (MICT) [20–24]. Nevertheless, HIIT is a time-efficient methodology that allows improvements in cardiorespiratory fitness and work capacity, mitochondrial muscle biogenesis and GLUT-4 levels, insulin sensitivity, fasting glucose, HbA1c and reduces several cardiometabolic risk factors in overweight/obese populations [25–27].

In addition, to our knowledge, there are no studies that analyze the effects of applying an ETP to increase or maintain muscle mass combining HIIT and resistance training with progressive loads. Although it has been amply demonstrated that resistance training with progressive resistance is safe, effective, and potentially more valid than aerobic exercise in many groups of patients [19], there is little scientific evidence to determine the exercise type, training loads to apply and results derived from ETP in patients with type III obesity awaiting BS.

The main purpose of this study was to determine the effects of a structured ETP, combining HIIT and resistance training with progressive workloads on the anthropometric profile, cardiometabolic risk factors (CRF), cardiorespiratory fitness and strength levels of patients with morbid obesity that are candidates for BS.

2. Materials and Methods

2.1. Participants

Six patients awaiting BS voluntarily took part in this study after being recommended to participate by the obesity surgery medical team both from the University Hospital of Vinalopó and the University General Hospital of Elche. They were divided, depending on their suitability possibilities to participate in a training program, into an experimental group (EG) or a control group (CG) that followed the usual medical care indications, see Table 1. Patients were eligible if they were awaiting BS and led a sedentary lifestyle (less than one hour of structured exercise weekly). The exclusion criteria were to suffer from: (a) any cardiovascular disease; (b) asthma or chronic obstructive pulmonary disease; (c) hypothyroidism or (d) functional limitations to perform an ETP. All participants were carefully informed about the risks associated with the study, and they were asked to sign an informed consent based on the Helsinki Declaration and approved by the University Ethical Committee.

Table 1. Baseline characteristics of participants before starting the exercise training program (ETP).

Variables	Total (n = 6)	EG (n = 3)	CG (n = 3)
Female (n)	5	2	3
Age (years)	38.17 ± 12.06	39.67 ± 10.21	36.67 ± 15.88
BMI (Kg·m ⁻²)	38.78 ± 1.18	38.02 ± 1.16	39.54 ± 0.64
Weight (Kg)	111.83 ± 14.10	114.43 ± 19.11	109.23 ± 10.57
Fat mass (%)	46.40 ± 4.89	44.17 ± 6.21	48.63 ± 2.51
FFM (%)	53.60 ± 4.89	55.83 ± 6.21	51.37 ± 2.51
Visceral fat (%)	14.00 ± 3.88	15 ± 5.51	13.00 ± 2.08
VO _{2peak abs} (L·min ⁻¹)	2.20 ± 0.86	2.62 ± 1.11	1.78 ± 0.29
VO _{2peak abs} /FFM (mL·FFM ⁻¹ ·min ⁻¹)	35.77 ± 7.14	39.92 ± 8.01	31.61 ± 3.40
Systolic blood pressure (mmHg)	131.89 ± 27.39	144.22 ± 37.39	119.56 ± 4.53
Diastolic blood pressure (mmHg)	77.94 ± 13.48	83.22 ± 18.68	72.67 ± 4.63

Values are mean ± SD. ETP = exercise training program; EG = experimental group; CG = control group; Kg = kilograms; m = metres; BMI = body mass index; FFM = fat free mass; VO_{2peak abs} = absolute peak oxygen uptake.

2.2. Procedure

All participants followed the usual presurgical care indications from their respective hospitals. The EG (n = 3) performed a six-month structured supervised ETP, in which the aerobic exercise they performed was carried out at high intensities and the resistance training was carried out with high workloads. The CG (n = 3) performed the same testing protocol, but without ETP.

The ETP was performed in the sports facilities of the University, under the direct supervision of sport sciences graduates. The weekly training frequency was established as two weekly sessions the first month up to four weekly sessions from the third month until the end of the program. The activities were individualized for each patient.

The EG and CG were tested a week before starting the ETP (E1), and six months after, at the end of the program (E3). In addition, the EG underwent an intermediate evaluation (E2) to check the evolution of the participants and to adapt the training loads. Body composition, cardiometabolic risk factors (CRF) and physical fitness were measured in a laboratory under controlled conditions.

2.3. Anthropometry, Body Composition and CRF Measurements

Patients visited the laboratory between 0700 and 0900 hours, after 12 h of overnight fasting, and with an empty bladder [28]. Caffeine or alcohol consumption and exercise were forbidden in the 48 h prior to the test. Total body weight and body composition were measured by bioimpedance analysis (Tanita BC-420MA, Tanita, Tokyo, Japan), and body mass index was calculated and expressed as kg·m⁻². Blood pressure was measured according to established recommendations [29] using a digital sphygmomanometer (Microlife WatchBP Home, Heerbrugg, Switzerland). Both weight and the waist and hip circumferences were measured using the ISAK (International Society for the Advancement of Kinanthropometry) protocol [30].

2.4. Cardiorespiratory Fitness Measurement

A two-phase protocol on a cycle ergometer (Technogym Bike Med, Technogym, Gambettola, Italy), adapted from a previous study [31] was performed to determine the peak oxygen uptake (VO_{2peak}) and fat oxidation rates. Respiratory exchange was registered with an Oxycon Pro gas analysis system (Jaeger, Friedberg, Germany). Carbohydrate oxidation (CHO) and fat oxidation (FO) were calculated in the first phase, while the second phase was used to establish the VO_{2peak}. The first phase consisted of performing a 4-min warm-up at 40 watts (W), followed by increases of 20 W every 3 min, maintaining a cadence of 60 rotations per minute (rpm). The first phase ended if the respiratory exchange ratio (RER) reached 1.0 or cadence values reduced to under 60 rpm. At this point, the second phase, consisting of

20 W increments each minute until volitional fatigue, started. To calculate the VO_{2peak} , the average of the highest 30 s of peak oxygen was used and it was expressed in absolute values ($VO_{2peak abs}$).

2.5. Muscle Strength Measurements

Maximal dynamic and isometric strength (MDS and MIS, respectively) of the quadriceps and hamstrings were assessed by an isokinetic dynamometer (Biodex System 4; Biodex Medical Systems, New York, NY, USA). Participants performed a 5-min warm-up on a cycle ergometer (Technogym Bike Med, Technogym, Gambettola, Italy) at an intensity of 60% maximal heart rate (HR_{max}) before starting the test. After that, participants were seated on the dynamometer chair, with the chair back inclined at an angle of 85° between hip and back. Two Velcro straps were used to avoid pelvis and torso movements. The dynamometer rotation axis was aligned with the lateral femoral epicondyle, allowing movement in the sagittal plane. Three unilateral tests were performed with each limb, one isokinetic test and two isometric tests. The dominant limb was evaluated first, followed by the non-dominant limb, with a two-minute rest between tests and a three-minute rest between limbs.

MDS. Four sets of four concentric contractions (flexion-extension) of the knee were performed at an angular speed of $60^\circ/s$, with 90 s rest between repetitions. The knee motion range was 10° – 105° . A first submaximal trial was performed to familiarize the participants with the protocol. The three following sets were performed at maximal individual effort, and participants were verbally encouraged to maintain their maximal effort in every contraction. The highest value of the last three sets was chosen to analyze the peak torque (N·m).

MIS. Participants completed a Maximum Voluntary Contraction (MVC) trial of four repetitions (the first set as a submaximal familiarization trial), with a fifteen-second rest between repetitions and were given verbal encouragement to perform at maximal effort for five seconds [32]. The angles used to assess the lower limbs were 105° for quadriceps and 75° for hamstrings.

2.6. Exercise Training Program (ETP)

A six-month ETP was performed by the EG, initially combining aerobic exercise at moderate intensities and resistance training to familiarise participants with physical exercise practice, see Table 2. The endurance training progressed from 60% to 95% VO_{2peak} intensities. The weekly frequency of the program was 2 days weekly (d/w) the first month, 3 d/w the second month, and 4 d/w from the third to the last month. The sessions lasted 60 minutes for the first two months and 70 minutes from the third to the last month. The endurance training days alternated MICT and HIIT. MICT sessions were performed from 60% to 85% HR_{peak} , while HIIT sessions were performed based on the percentage of VO_{2peak} . The HIIT programs were only performed on a cycle ergometer and consisted of intervals of 30 s of work interspersed by 30 s of active recovery at 30% VO_{2peak} . The MICT was carried out on a treadmill or on a cycle ergometer.

Resistance training was carried out after HIIT in the same session, prescribed based on the percentage of one repetition maximum (1RM), which was determined using the Brzycki formula [33]. The exercises (latissimus dorsi, pectorals, quadriceps, hamstrings, gastrocnemius, deltoids, triceps, and biceps brachial) were performed using guided machines with weights that ranged between 50% of 1RM and 75% of 1RM. All the sessions finished with five stretching exercises in standing (gastrocnemius, quadriceps, hamstrings, pectorals and latissimus dorsi).

To provide an internal load measure and to control the training process, each participant's rating of perceived exertion (RPE) was collected using the CR-10 Borg's scale [34]. RPE was taken 30 min after the end of each session, in order to prevent difficult or easy exercises near the end of the session that could influence the overall rating of the session [35].

Table 2. ETP schedule (EG).

Month		1	2	3	4	5	6
MICT	Weekly frequency (sessions/week)	2	1	2	2	2	2
	Volume (min)	35	50	50	50	50	50
	Intensity (% HR _{peak})	60–70	65–75	70–80	70–85	70–85	70–85
HIIT	Weekly frequency (sessions/week)		2	2	2	2	2
	Volume (min)		20	20	20	20	20
	Intensity (% VO _{2peak})		60–70	70–80	75–85	80–90	80–95
Resistance training	Weekly frequency (sessions/week)	2	2	2	2	2	2
	Volume (series × exer. × rep.)	1 × 5 × 20	1 × 7 × 20	4 × 4 × 15	4 × 4 × 12	4 × 4 × 10	4 × 4 × 10
	Intensity (% 1RM)	55	60	65	70	75	75
Stretching training	Weekly frequency (sessions/week)	2	3	4	4	4	4
	Volume (series × exer.)	1 × 5	1 × 5	1 × 5	1 × 5	1 × 5	1 × 5
	Duration (min)	1	1	1	1	1	1

ETP = exercise training program; EG = experimental group; MICT= moderate-intensity continuous training; HIIT = high-intensity interval training; % HR_{peak} = peak heart rate percentage; min = minutes; % VO_{2peak} = peak oxygen uptake percentage; exer. × rep. = number of exercises performed and number of repetitions by exercise; % 1RM = percentage over a maximum repetition.

2.7. Statistical Analysis

The data are presented as mean (\pm SD). The normal distribution of all data series was verified by the Kolmogorov–Smirnov test. A one-factor ANOVA was used to check the changes produced in physical condition, body composition and cardiometabolic variables for each of the two testing moments (pre-program vs post-program). A t-test was performed for multiple within-group comparisons when ANOVA showed significant interaction effects among groups.

All data were log-transformed for the analysis to reduce bias arising from non-uniformity error and then they were analyzed for practical significance using magnitude-based inferences [36]. The effect size (ES) was calculated using Cohen’s coefficient [37], which allowed the magnitude of the changes between the test and the post-test to be established based on the performance of the training session (i.e., ES of ≥ 0.2 = small; ≥ 0.5 = moderate; ≥ 0.8 = large magnitudes of change, respectively). Descriptors were used to interpret the probabilities of effects (clinical inferences based on threshold chances of harm and benefit of 0.5% and 25%) [38]. The probability that the true effects are harmful, trivial or beneficial was considered as the following: <1%, almost certainly not; 1–4%, very unlikely; 5–24%, unlikely or probably not; 25–74%, possibly or maybe; 75–94%, likely or probable; 95–99%, very likely; >99%, almost certainly [38]. Changes in mean were also included for each group (expressed in %) and their 90% confidence limits (CL).

Statistical analysis was performed with the SPSS package program (version 22, SPSS Inc., Chicago, IL, USA) and the null hypothesis was rejected at the 95% significance level ($p \leq 0.05$). For clarity, all results are presented as positive improvements, so that negative and positive differences can be viewed in the same direction.

3. Results

3.1. Description of the Dynamic Loads Performed by the Experimental Group

The EG participated in $93.25 \pm 6.5\%$ of the sessions, without any injury or adverse event experienced. Internal load values (calculated as the product of total session time duration and intensity), the monotony and the strain index during each week of ETP are shown in Figure 1.

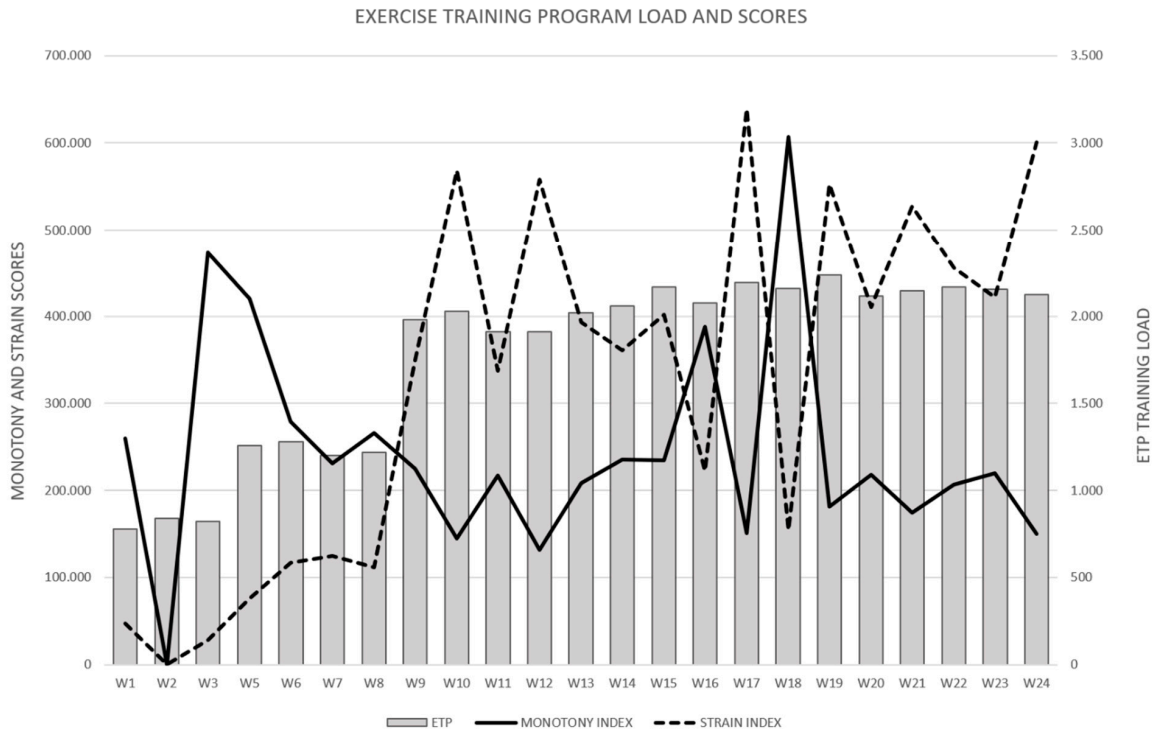
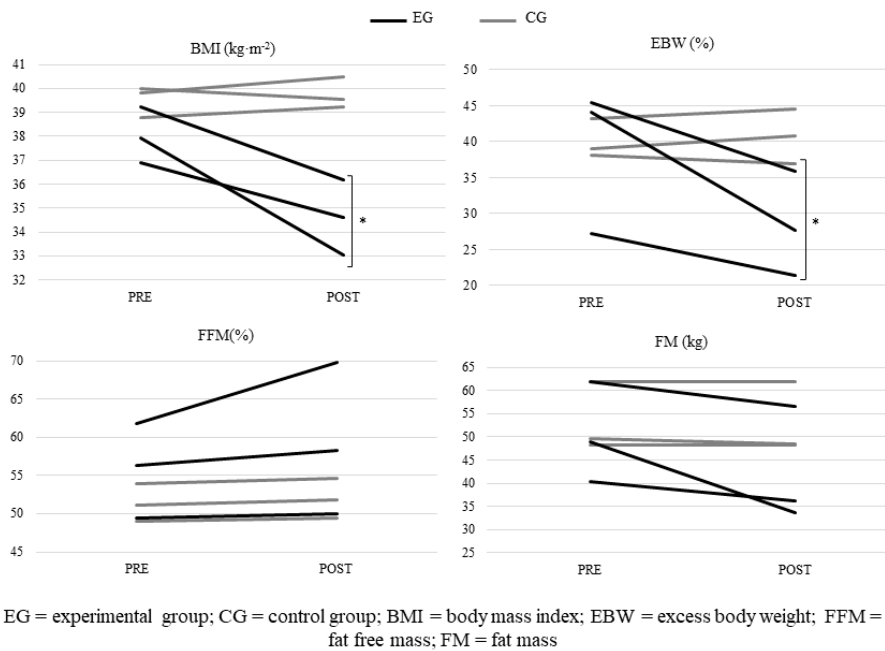


Figure 1. Load dynamics and scores during each week of ETP. W = week; ETP = exercise training program. * Week 4 does not show load values because 1RM tests were performed.

3.2. Anthropometry and Body Composition

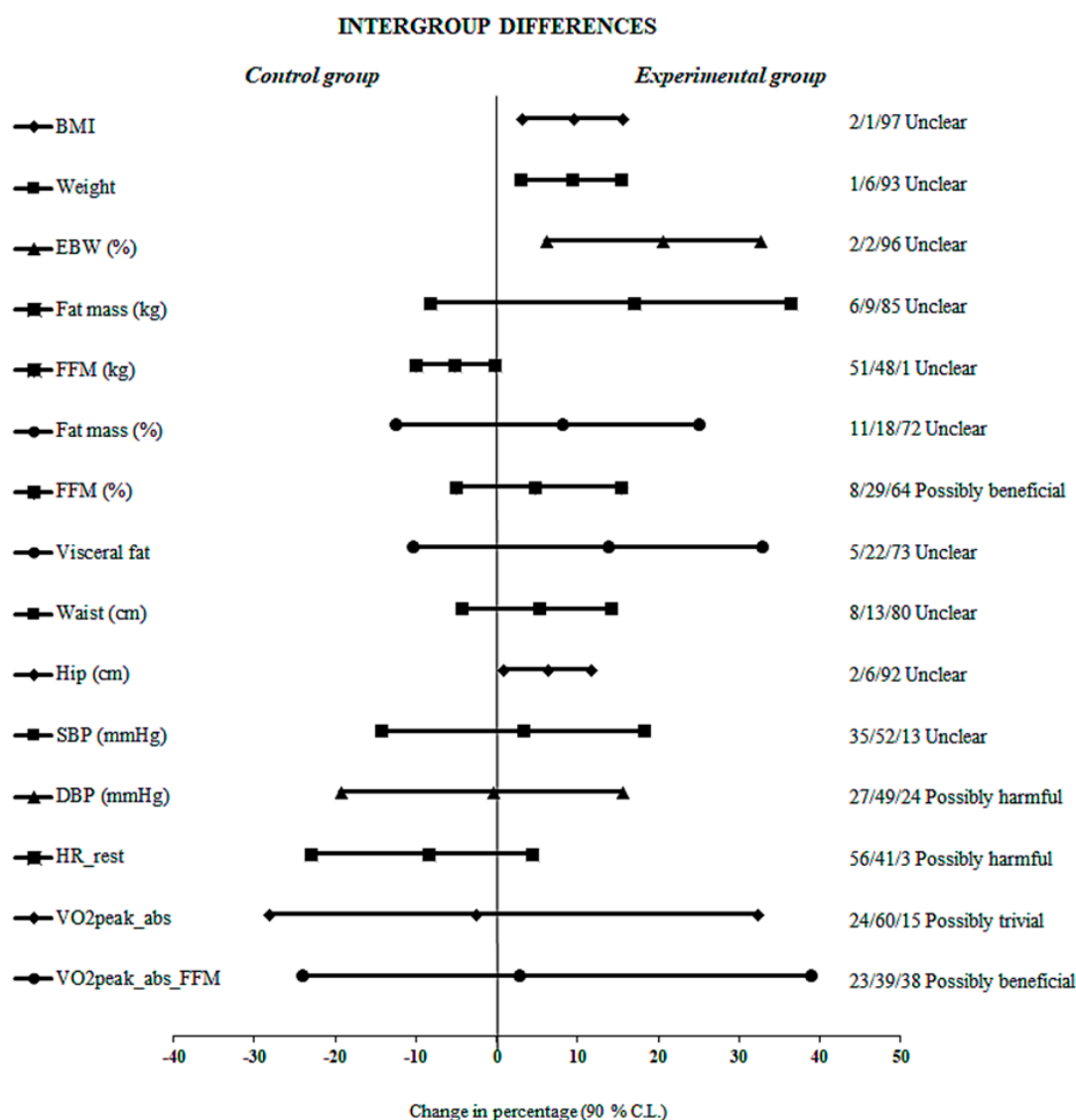
After performing the ETP, ANOVA showed no statistically significant differences in all the variables evaluated in the EG, except in BMI and excess body weight percentage (EBW%), which had higher significant reductions than the CG ($34.61 \pm 1.56\%$ vs $39.75 \pm 0.65\%$, $p = 0.006$, and $27.00 \pm 4.06\%$ vs $37.10 \pm 1.02\%$, $p = 0.014$, respectively), as shown in Figure 2.



EG = experimental group; CG = control group; BMI = body mass index; EBW = excess body weight; FFM = fat free mass; FM = fat mass

Figure 2. Changes in each participant in body composition variables after vs before ETP (* $p < 0.05$). There was no significant difference between the two groups for values observed before training.

T-test results are shown in Table 3 for the CG and EG, while among-group differences in the variables considered as the most relevant ones are represented in Figure 3. The EG shows a larger ES on BMI, EBW (kg, %) and fat mass (kg, %), which is not observed in the CG. In addition, all the anthropometric measurements showed small to moderate ES except FFM (kg) values. The inferential analysis showed unclear effects in BMI, EBW (kg, %), fat mass percentage (FM%) and visceral fat with a probability of $\geq 80\text{--}95\%$. However, likely positive effects with a probability of $>95\text{--}99\%$ were shown in the fat-free mass percentage (FFM%). Finally, two correlations between fat mass (kg) and FFM%, FM% and hip circumference were observed ($r = -0.875$ and $r = 0.822$, respectively). Qualitative inference and likelihood (%) of the effects being positive/trivial/negative for each of the groups could be consulted in Table S1.



CL = coefficient limits; BMI = body mass index; EBW = excess body weight; FFM = fat free mass; SBP = systolic blood pressure; DBP = diastolic blood pressure; HR_{rest} = heart rate at rest; VO_{2peak abs} = absolute peak oxygen uptake; VO_{2peak abs/FFM} = absolute peak oxygen uptake normalized to FFM

Figure 3. Changes in anthropometric measurements, cardiometabolic risk factors and physical fitness variables among groups.

Table 3. Descriptive characteristics (mean \pm SD) on anthropometric measurements before and after the ETP for each of the groups.

Variables	EG (n = 3)			CG (n = 3)		
	Pre	Post	ES (d) (90% CL)	Pre	Post	ES (d) (90% CL)
BMI (kg·m⁻²)	38.02 \pm 1.16	34.61 \pm 1.56 *	3.30 (1.05; 5.54)	39.54 \pm 0.64	39.75 \pm 0.65	-0.19 (-1.03; 0.66)
Weight (kg)	114.43 \pm 19.11	103.87 \pm 14.80	0.57 (0.18; 0.57)	109.23 \pm 10.57	109.87 \pm 11.43	-0.03 (-0.18; 0.11)
EBW (kg)	38.83 \pm 10.14	28.27 \pm 7.27	2.71 (0.79; 4.62)	40.09 \pm 2.70	40.72 \pm 3.74	-0.12 (-0.68; 0.43)
EBW (%)	33.55 \pm 3.89	27.00 \pm 4.06 †	4.42 (1.19; 7.65)	36.77 \pm 1.04	37.10 \pm 1.02	-0.18 (-1.00; 0.63)
Fat mass (kg)	50.48 \pm 10.87	42.16 \pm 12.52	0.81 (-0.30; 1.91)	53.25 \pm 7.49	52.91 \pm 7.91	0.03 (-0.08; 0.14)
Fat mass (%)	44.17 \pm 6.21	40.63 \pm 9.94	-1.08 (-1.15; 3.31)	48.63 \pm 2.51	48.03 \pm 2.65 *	0.14 (0.06; 0.21)
FFM (kg)	63.95 \pm 13.83	61.71 \pm 14.39	-0.32 (-0.70; 0.07)	55.98 \pm 3.80	56.96 \pm 4.40	0.14 (-0.05; 0.33)
FFM (%)	55.83 \pm 6.21	59.37 \pm 9.94	0.66 (-0.48; 1.80)	51.37 \pm 2.51	51.97 \pm 2.65 *	0.14 (0.08; 0.19)
Waist (cm)	120.27 \pm 4.07	114.26 \pm 5.68	0.37 (-0.31; 1.05)	115.62 \pm 9.10	116.02 \pm 8.18	-0.03 (-0.21; 0.16)
Hip (cm)	130.57 \pm 10.76	122.27 \pm 13.63 †	0.69 (0.12; 1.26)	134.04 \pm 7.64	133.70 \pm 8.72	0.03 (-0.14; 0.20)
WHR (cm)	0.93 \pm 0.09	0.94 \pm 0.06	-0.10 (-0.54; 0.35)	0.86 \pm 0.08	0.87 \pm 0.08	-0.04 (-0.10; 0.02)
Visceral fat (%)	14.67 \pm 5.51	12 \pm 2.65	0.62 (-0.24; 1.47)	12.67 \pm 2.08	12.33 \pm 1.53	0.08 (-0.16; 0.32)

PAP = physical activity program; EG = experimental group; CG = control group; CL = coefficient limits; BMI = body mass index; EBW = excess body weight; FFM = fat free mass; WHR = waist-to-hip ratio. * Statistical significant intragroup differences ($p < 0.05$, paired t-test). † ($p = 0.052$; $p = 0.059$, paired t-test).

Table 4. Descriptive characteristics (mean \pm SD) on cardiometabolic risk factors and physical fitness variables before and after the PAP, for each of the groups.

Variables	EG (n = 3)			CG (n = 3)		
	Pre	Post	ES (d) (90% CL)	Pre	Post	ES (d) (90% CL)
SBP (mmHg)	144.22 \pm 37.39	139.28 \pm 28.76	0.41 (−2.02; 2.84)	119.56 \pm 4.53	120.61 \pm 8.92	−0.11 (−2.09; 1.86)
DBP (mmHg)	83.22 \pm 18.68	79.83 \pm 18.37	0.37 (−0.53; 1.28)	72.67 \pm 4.63	69.39 \pm 6.09	0.42 (−1.23; 2.06)
HR _{rest} (bpm)	56.33 \pm 12.34	62.00 \pm 11.53	−0.26 (−0.54; 0.03)	65.67 \pm 13.58	66.67 \pm 13.32	−0.04 (−0.32; 0.23)
VO _{2peak abs} (L·min ^{−1})	2.62 \pm 1.11	2.69 \pm 1.04	0.11 (−0.12; 0.35)	1.78 \pm 0.29	1.89 \pm 0.37	0.21 (−0.85; 1.28)
VO _{2peak abs/FFM} (mL·FFM ^{−1} ·min ^{−1})	39.92 \pm 8.01	42.58 \pm 6.24	0.38 (−0.23; 0.99)	31.61 \pm 3.40	33.07 \pm 4.45	0.23 (−1.29; 1.76)
MDS _{D-Q} (N·m)	151.84 \pm 36.10	155.16 \pm 43.38	0.05 (−0.36; 0.45)	144.12 \pm 21.46	149.50 \pm 18.35	0.14 (−0.16; 0.45)
MDS _{D-H} (N·m)	86.53 \pm 24.87	84.54 \pm 17.37	−0.02 (−0.53; 0.48)	66.06 \pm 18.67	59.93 \pm 14.97	−0.17 (−0.40; 0.07)
MDS _{ND-Q} (N·m)	149.88 \pm 47.94	161.74 \pm 54.86	0.35 (0.13; 0.58)	141.14 \pm 15.73	142.03 \pm 19.00	0.02 (−0.44; 0.49)
MDS _{ND-H} (N·m)	75.81 \pm 14.93	85.66 \pm 21.93	0.56 (−0.21; 1.32)	57.03 \pm 6.42	60.81 \pm 6.69	0.32 (0.06; 0.57)
MIS _{D-Q} (N·m)	141.90 \pm 19.18	139.77 \pm 21.19	−0.07 (−0.30; 0.16)	138.76 \pm 19.35	130.11 \pm 3.89	−0.24 (−1.02; 0.54)
MIS _{D-H} (N·m)	95.83 \pm 23.39	90.53 \pm 12.71	−0.12 (−0.69; 0.45)	72.16 \pm 15.02	62.48 \pm 14.31	−0.37 (−1.20; 0.45)
MIS_{ND-Q} (N·m)	147.50 \pm 3.47	151.73 \pm 16.01	0.11 (−0.48; 0.69)	133.61 \pm 17.80	121.02 \pm 8.40	−0.40 (−0.90; 0.10)
MIS _{ND-H} (N·m)	90.30 \pm 15.95	89.10 \pm 15.30	−0.02 (−0.32; 0.28)	61.71 \pm 19.85	61.18 \pm 10.31	−0.03 (−0.52; 0.46)

PAP = physical activity program; EG = experimental group; CG = control group; CL = coefficient limits; SBP = systolic blood pressure; DBP = diastolic blood pressure; HR_{rest} = heart rate at rest; VO_{2peak abs} = absolute peak oxygen uptake; VO_{2peak abs/FFM} = absolute peak oxygen uptake normalized to FFM; MDS = maximal dynamic strength; D = dominant; ND = non-dominant; Q = quadriceps; H = hamstrings; MIS = maximal isokinetic strength. * Statistical significant intragroup differences ($p < 0.05$).

3.3. Physical Fitness and Cardiometabolic Risk Factors

After performing the ETP, significant differences among groups were found in MDS normalized to FFM (MDSFFM) in the non-dominant (ND) limb hamstrings (EG = $138.34 \pm 3.29 \text{ N}\cdot\text{m}\cdot\text{FFM}^{-1}$ vs CG = $106.68 \pm 6.77 \text{ N}\cdot\text{m}\cdot\text{FFM}^{-1}$; $p = 0.002$), as well as in MIS in the ND hamstrings normalized to FFM (EG = $145.68 \pm 8.41 \text{ N}\cdot\text{m}\cdot\text{FFM}^{-1}$ vs CG = $106.98 \pm 10.85 \text{ N}\cdot\text{m}\cdot\text{FFM}^{-1}$; $p = 0.008$) and in the ND quadriceps (EG = $151.73 \pm 16.01 \text{ N}\cdot\text{m}$ vs CG = $121.02 \pm 8.40 \text{ N}\cdot\text{m}$; $p = 0.042$).

T-test results are shown in Table 4 for the CG and EG, respectively. Both the EG and the CG showed improvements in diastolic blood pressure (DBP), $\text{VO}_{2\text{peak}}$ when it was normalized to FFM ($\text{VO}_{2\text{peak abs}}/\text{FFM}$) and ND hamstring MDS level, but only the EG improved hip circumference, systolic blood pressure (SBP) and MDS level in the ND quadriceps. However, the EG showed small and moderate effects on MDS in the ND lower limb both in quadriceps ($dQ = 0.35$, likely beneficial) and hamstrings ($dH = 0.56$, likely beneficial), while inferior results were found in the CG for the same variables ($dQ = 0.02$, possibly trivial; $dH = 0.32$, likely beneficial). Qualitative inference and likelihood (%) of the effects being positive/trivial/negative for each of the groups can be consulted in Table S1.

4. Discussion

Our pilot study suggests that a six-month ETP, combining long-term HIIT with resistance training from 55% to 75% 1RM seems to be a positive intervention to improve body composition, CRF and physical condition in patients awaiting BS. Despite the limitations associated with our small sample size, this pilot study could be useful as a starting point to design future research with similar physical activity interventions. The ETP could be feasible since subjects participated in >90% of the total supervised sessions proposed, which resulted in practical significant improvements in most of the anthropometrical variables, SBP, DBP, cardiorespiratory fitness and maximal strength level in the non-dominant lower limb. To our knowledge, this study is the first to examine the effects of an ETP combining endurance and resistance training with a programmed and monitored workload in this population.

The results related to changes in FM observed in the EG could explain significant reductions in BMI and EBW% ($p < 0.05$). Participants in the EG showed FM and visceral fat reductions after the ETP, while FFM remained constant. Therefore, FFM% increased after the ETP. Conservative weight loss programs aim to lose from 5% to 10% body weight to be able to consider a reduction as clinically significant to decrease surgical risk [39]. In this pilot study, the EG showed a decrease close to 6% in EBW% (33.55 ± 3.89 vs 27.00 ± 4.06 , $p = 0.052$). Consequently, our ETP seems to be a positive tool that could be analyzed and added to traditional weight loss programs to complement the effects associated with pharmacological, psychological and nutritional treatments in patients awaiting BS. In fact, a recent study showed that a twice-weekly low-intensity physical activity program encouraged individuals to adopt a more active lifestyle, both with and without the aid of support group therapy for lifestyle modification [40]. Therefore, multidisciplinary treatments that include physical activity could be the key to optimize not only weight loss parameters before surgery, but also the surgical risk and health status of patients, helping them to adopt more physically active lifestyles.

There are no standardized guidelines to establish recommendations of physical activity in obese patients awaiting BS. Previous studies [4,17,41] have performed aerobic exercise combined with resistance training which reported changes in body composition and anthropometrical variables. Our pilot study is characterized by programming and monitoring workloads over a six-month period, showing higher reductions in waist and hip circumferences, BMI, body weight, FM and visceral fat percentages than results reported by similar studies [8,17,42]. These results could be explained by two reasons: a) The longer duration of our program (84 training sessions in total), and b) the individualization of training prescription according to percentages of their $\text{VO}_{2\text{peak}}$ and 1RM tests. In addition, none of these interventions compare their results with a CG that followed the usual care indications, so it is difficult to interpret the effect that is directly associated with physical activity. Only Baillot et al. [42] compared the effects of a 12-week intervention with a CG, the results of which did not

present changes in body composition and CRF. Conversely, our data show differences with practical significance in body composition, among patients that performed a structured ETP or followed the usual medical care; therefore it can be guaranteed that changes are not a consequence of a traditional BS treatment preparation exclusively.

Small to moderate changes were observed in most of the CRF and physical condition variables after performing an ETP. Both the EG and the CG showed improvements in some maximal muscle strength variables. However, although the EG showed higher changes in $VO_{2peak\ abs}/FFM$, the CG improved $VO_{2peak\ abs}$ as well, so no influence of the previous experience of participants during E1 could be implied. Because severely obese adults often suffer from chronic knee pain, breathing arrhythmia and exercise intolerance [43], patients could be limited to performing a maximal test to prevent injuries or negative experiences. Thus, these results could be explained by the absence of learning sessions of both isokinetic and cardiorespiratory test protocols. Therefore, these sessions could be an alternative so that patients get to know each protocol, and consequently, to check that the results obtained are consistent and reliable.

Our results in MDS levels can be explained by excessive intra- and intermuscular fat accumulation which characterizes our population and influences both the force generation and the functional capacity of a skeletal muscle negatively. Although our ETP is related to FM% and fat visceral reductions, the electrical bioimpedance method cannot discriminate the body area in which greater FM has been reduced. A recent study [44] has suggested that FFM, mainly in the lower limbs, is crucial to increase the absolute MVC torques and, consequently, to prevent losses of muscle strength and functional limitations. Therefore, it could be because our participants did not show significant differences in MDS and MIS after performing an ETP as FFM remained constant and changes in FFM% were a direct consequence of body weight reduction due to FM decrease.

All participants were sedentary adults with no previous experience in practicing physical activity. This is particularly interesting since one of the most relevant practical problems for exercise professionals is the amount of physical activity required to reach specific outcomes without a negative impact. Although our ETP was performed with high workloads, no significant changes in training load were registered from the third to the sixth month of the ETP, see Figure 1. This could imply that patients with severe obesity likely need approximately eight weeks, see Figure 1, to adapt to the systematic practice of physical activity. In addition, the strain of training was well-controlled through interspersing combined high-intensity training sessions (HIIT and resistance training) with MICT sessions from the second to the sixth month, which could explain why no participants suffered any injury during the ETP.

5. Conclusions

In summary, our data suggest that a six-month ETP could be a positive and safe intervention to support traditional weight loss treatments for patients awaiting BS. However, this pilot study is not enough to establish specific guidelines. Future studies with a larger sample size are needed to confirm these benefits which are apparently associated with an ETP before BS. In addition, post-surgery data would be interesting to be able to assess the real effectivity to reduce surgical risk and improve the recovery process.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2075-4663/7/3/72/s1>, Table S1: Changes (%) in all the variables evaluated. Qualitative inference and likelihood (%) of the effects being positive/trivial/negative for each of the groups.

Author Contributions: Conceptualization, I.P.-S. and M.M.-R.; methodology, I.P.-S. and M.M.-R.; formal analysis, I.P.-S. and M.M.-R.; investigation, I.P.-S.; resources, M.M.-R.; data curation, D.P., A.A.-M. and M.M.-R.; writing—original draft preparation, I.P.-S.; writing—review and editing, D.P., A.A.-M. and M.M.-R.; supervision, A.A.-M. and M.M.-R.; project administration, M.M.-R.

Funding: This research received no external funding.

Acknowledgments: We would like to thank the medical teams of the Vinalopó University Hospital and the Elche General University Hospital for their collaboration recommending our programme to patients awaiting bariatric surgery.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Banegas, J.R.; Lopez-Garcia, E.; Gutierrez-Fisac, J.L.; Guallar-Castillon, P.; Rodriguez-Artalejo, F. A simple estimate of mortality attributable to excess weight in the European Union. *Eur. J. Clin. Nutr.* **2003**, *57*, 201–208. [[CrossRef](#)] [[PubMed](#)]
2. Allison, D.B.; Fontaine, K.R.; Manson, J.E.; Stevens, J.; VanItallie, T.B. Annual deaths attributable to obesity in the United States. *JAMA* **1999**, *282*, 1530–1538. [[CrossRef](#)] [[PubMed](#)]
3. Floody, P.D.; Mayorga, D.J.; Navarrete, F.C.; Díaz, M.C.; Elgueta, H.O.; Poblete, A.O. Efectividad del tratamiento integral sobre las condiciones preoperatorias de mujeres obesas candidatas a cirugía bariátrica. *Nutr. Hosp.* **2015**, *32*, 2570–2575.
4. Moya, M.; Hernández, A.; Sarabia, J.M.; Sánchez-Martos, M.A.; Hernández-Davó, J.L.; López-Gruoso, R.; Aracil, A.; Pastor, D.; Fernández-Fernández, J. Bariatric surgery, weight loss and the role of physical activity: A systematic review. *Eur. J. Hum. Mov.* **2014**, *32*, 145–160.
5. Clark, J.E. Diet, exercise or diet with exercise: Comparing the effectiveness of treatment options for weight-loss and changes in fitness for adults (18–65 years old) who are overfat, or obese; systematic review and meta-analysis. *J. Diabetes Metab. Disord.* **2015**, *14*, 1–28.
6. Sjöström, L. Review of the key results from the Swedish Obese Subjects (SOS) trial—a prospective controlled intervention study of bariatric surgery. *J. Intern. Med.* **2013**, *273*, 219–234. [[CrossRef](#)]
7. King, W.C.; Hsu, J.Y.; Belle, S.H.; Courcoulas, A.P.; Eid, G.M.; Flum, D.R.; Mitchell, J.E.; Pender, J.R.; Smith, M.D.; Steffen, K.J.; et al. Pre-to postoperative changes in physical activity: Report from the longitudinal assessment of bariatric surgery-2 (LABS-2). *Surg. Obes. Relat. Dis.* **2012**, *8*, 522–532. [[CrossRef](#)] [[PubMed](#)]
8. Sánchez Ortega, L.; Sánchez Juan, C.; Alfonso García, A. Valoración de un programa de ejercicio físico estructurado en pacientes con obesidad mórbida pendientes de cirugía bariátrica. *Nutr. Hosp.* **2014**, *29*, 64–72.
9. Van Wissen, J.; Bakker, N.; Doodeman, H.J.; Jansma, E.P.; Bonjer, H.J.; Houdijk, A.P.J. Preoperative methods to reduce liver volume in bariatric surgery: A systematic review. *Obes. Surg.* **2016**, *26*, 251–256. [[CrossRef](#)] [[PubMed](#)]
10. Guida, B.; Cataldi, M.; Busetto, L.; Aiello, M.L.; Musella, M.; Capone, D.; Parolisi, S.; Policastro, V.; Ragozini, G.; Belfiore, A. Predictors of fat-free mass loss 1 year after laparoscopic sleeve gastrectomy. *J. Endocrinol. Invest.* **2018**, *41*, 1307–1315. [[CrossRef](#)] [[PubMed](#)]
11. Castello, V.; Simões, R.P.; Bassi, D.; Catai, A.M.; Arena, R.; Borghi-Silva, A. Impact of aerobic exercise training on heart rate variability and functional capacity in obese women after gastric bypass surgery. *Obes. Surg.* **2011**, *21*, 1739–1749. [[CrossRef](#)] [[PubMed](#)]
12. Shah, M.; Snell, P.G.; Rao, S.; Adams-Huet, B.; Quittner, C.; Livingston, E.H.; Garg, A. High-Volume Exercise Program in Obese Bariatric Surgery Patients: A Randomized, Controlled Trial. *Obesity* **2011**, *19*, 1826–1834. [[CrossRef](#)]
13. Stegen, S.; Derave, W.; Calders, P.; Van Laethem, C.; Pattyn, P. Physical fitness in morbidly obese patients: Effect of gastric bypass surgery and exercise training. *Obes. Surg.* **2011**, *21*, 61–70. [[CrossRef](#)]
14. Baillet, A.; Vallée, C.A.; Mampuya, W.M.; Dionne, I.J.; Comeau, E.; Méziat-Burdin, A.; Langlois, M.F. Effects of a Pre-surgery Supervised Exercise Training 1 Year After Bariatric Surgery: A Randomized Controlled Study. *Obes. Surg.* **2018**, *28*, 955–962. [[CrossRef](#)] [[PubMed](#)]
15. Bond, D.S.; Thomas, J.G.; King, W.C.; Vithiananthan, S.; Trautvetter, J.; Unick, J.L.; Ryder, B.A.; Pohl, D.; Roye, G.D.; Sax, H.C.; et al. Exercise improves quality of life in bariatric surgery candidates: Results from the Bari-Active trial. *Obesity* **2015**, *23*, 536–542. [[CrossRef](#)] [[PubMed](#)]
16. Floody, P.D.; Mayorga, D.J.; Navarrete, F.C.; Poblete, A.O.; Lepeley, N.T.; Hormazábal, M.A. Doce semanas de ejercicio físico intervalado con sobrecarga mejora las variables antropométricas de obesos mórbidos y obesos con comorbilidades postulantes a cirugía bariátrica. *Nutr. Hosp.* **2015**, *32*, 2007–2011.

17. Baillot, A.; Mampuya, W.M.; Comeau, E.; Méziat-Burdin, A.; Langlois, M.F. Feasibility and impacts of supervised exercise training in subjects with obesity awaiting bariatric surgery: A pilot study. *Obes. Surg.* **2013**, *23*, 882–891. [[CrossRef](#)]
18. Kalarchian, M.A.; Marcus, M.D.; Courcoulas, A.P.; Cheng, Y.; Levine, M.D. Preoperative lifestyle intervention in bariatric surgery: Initial results from a randomized, controlled trial. *Obesity* **2013**, *21*, 254–260. [[CrossRef](#)] [[PubMed](#)]
19. Adair, J.D.; Wollner, S.B.; DaCosta, M.E.; Blackburn, G.L. Progressive resistance training for patients with class III obesity. *Obes. Weight Manag.* **2010**, *6*, 115–118. [[CrossRef](#)]
20. Keating, S.E.; Johnson, N.A.; Mielke, G.I.; Coombes, J.S. A systematic review and meta-analysis of interval training versus moderate-intensity continuous training on body adiposity. *Obes. Rev.* **2017**, *18*, 943–964. [[CrossRef](#)] [[PubMed](#)]
21. Robinson, E.; Durrer, C.; Simtchouk, S.; Jung, M.E.; Bourne, J.E.; Voth, E.; Little, J.P. Short-term high-intensity interval and moderate-intensity continuous training reduce leukocyte TLR4 in inactive adults at elevated risk of type 2 diabetes. *J. Appl. Physiol.* **2015**, *119*, 508–516. [[CrossRef](#)]
22. Lanzi, S.; Codecasa, F.; Cornacchia, M.; Maestrini, S.; Capodaglio, P.; Brunani, A.; Salvadori, A.; Malatesta, D. Short-term HIIT and Fatmax training increase aerobic and metabolic fitness in men with class II and III obesity. *Obesity* **2015**, *23*, 1987–1994. [[CrossRef](#)]
23. Fisher, G.; Brown, A.W.; Bohan Brown, M.M.; Alcorn, A.; Noles, C.; Winwood, L.; Resuehr, H.; George, B.; Jeansonne, M.M.; Allison, D.B. High Intensity Interval-vs Moderate Intensity-Training for Improving Cardiometabolic Health in Overweight or Obese Males: A Randomized Controlled Trial. *PLoS ONE* **2015**, *10*, e0138853. [[CrossRef](#)]
24. Little, J.P.; Jung, M.E.; Wright, A.E.; Wright, W.; Manders, R.J. Effects of high-intensity interval exercise versus continuous moderate-intensity exercise on postprandial glycemic control assessed by continuous glucose monitoring in obese adults. *Appl. Physiol. Nutr. Metab.* **2014**, *39*, 835–841. [[CrossRef](#)]
25. Batacan, R.B.; Duncan, M.J.; Dalbo, V.J.; Tucker, P.S.; Fenning, A.S. Effects of high-intensity interval training on cardiometabolic health: A systematic review and meta-analysis of intervention studies. *Br. J. Sports Med.* **2017**, *51*, 494–503. [[CrossRef](#)]
26. Keating, S.E.; Machan, E.A.; O'Connor, H.T.; Gerofi, J.A.; Sainsbury, A.; Caterson, I.D.; Johnson, N.A. Continuous exercise but not high intensity interval training improves fat distribution in overweight adults. *J. Obes.* **2014**, *2014*, 834865. [[CrossRef](#)] [[PubMed](#)]
27. Jelleyman, C.; Yates, T.; O'Donovan, G.; Gray, L.J.; King, J.A.; Khunti, K.; Davies, M.J. The effects of high-intensity interval training on glucose regulation and insulin resistance: A meta-analysis. *Obes. Rev.* **2015**, *16*, 942–961. [[CrossRef](#)] [[PubMed](#)]
28. Kyle, U.G.; Bosaeus, I.; De Lorenzo, A.D.; Deurenberg, P.; Elia, M.; Manuel Gómez, J.; Lilienthal Heitmann, B.; Kent-Smith, L.; Melchior, J.C.; Pirlich, M.; et al. Bioelectrical impedance analysis—Part II: Utilization in clinical practice. *Clin. Nutr.* **2004**, *23*, 1430–1453. [[CrossRef](#)]
29. Pickering, T.G.; Hall, J.E.; Appel, L.J.; Falkner, B.E.; Graves, J.; Hill, M.N.; Jones, D.W.; Kurtz, T.; Sheps, S.G.; Roccella, E.J. Recommendations for blood pressure measurement in humans and experimental animals: Part 1: Blood pressure measurement in humans: A statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. *Hypertension* **2005**, *45*, 142–161. [[PubMed](#)]
30. Marfell-Jones, M.; Stewart, A.; de Ridder, J.H. *International Standards for Anthropometric Assessment*; The International Society for the Advancement of Kinanthropometry: Wellington, New Zealand, 2012.
31. Achten, J.; Gleeson, M.; Jeukendrup, A.E. Determination of the exercise intensity that elicits maximal fat oxidation. *Med. Sci. Sports Exerc.* **2002**, *34*, 92–97. [[CrossRef](#)]
32. Symons, T.B.; Vandervoort, A.; Rice, C.L.; Overend, T.J.; Marsh, G.D. Effects of maximal isometric and isokinetic resistance training on strength and functional mobility in older adults. *J. Gerontol. A Biol. Sci. Med. Sci.* **2005**, *60*, 777–781. [[CrossRef](#)]
33. Brzycki, M. Strength testing—predicting a one-rep max from reps-to-fatigue. *J. Phys. Health Educ. Recreat. Dance* **1993**, *64*, 88–90. [[CrossRef](#)]
34. Borg, G.A. Psychophysical bases of perceived exertion. *Med. Sci. Sports Exerc.* **1982**, *14*, 377–381. [[CrossRef](#)]
35. Foster, C.; Florhaug, J.A.; Franklin, J.; Gottschall, L.; Hrovatin, L.A.; Parker, S.; Doleshal, P.; Dodge, C. A new approach to monitoring exercise training. *J. Strength Cond. Res.* **2001**, *15*, 109–115. [[PubMed](#)]

36. Hopkins, W.G.; Marshall, S.W.; Batterham, A.M.; Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med. Sci. Sports Exerc.* **2009**, *41*, 3–12. [[CrossRef](#)] [[PubMed](#)]
37. Cohen, J. *Statistical Analysis for the Behavioral Sciences*; Lawrence Erlbaum Associates: Hillsdale, NJ, USA, 1988.
38. Batterham, A.M.; Hopkins, W.G. Making meaningful inferences about magnitudes. *Int. J. Sports Physiol. Perform.* **2006**, *1*, 50–57. [[CrossRef](#)] [[PubMed](#)]
39. Herpertz, S.; Kessler, H.; Jongen, S. Psychosomatic and Psychosocial Questions Regarding Bariatric Surgery: What Do We Know, or What Do We Think We Know? *Z. Psychosom. Med. Psychother.* **2017**, *63*, 344–369. [[CrossRef](#)] [[PubMed](#)]
40. Marcon, E.R.; Baglioni, S.; Bittencourt, L.; Lopes, C.L.N.; Neumann, C.R.; Trindade, M.R.M. What is the best treatment before bariatric surgery? Exercise, exercise and group therapy, or conventional waiting: A randomized controlled trial. *Obes. Surg.* **2017**, *27*, 763–773. [[CrossRef](#)] [[PubMed](#)]
41. Baillot, A.; Mampuya, W.M.; Dionne, I.J.; Comeau, E.; Méziat-Burdin, A.; Langlois, M.F. Impacts of supervised exercise training in addition to interdisciplinary lifestyle management in subjects awaiting bariatric surgery: A randomized controlled study. *Obes. Surg.* **2016**, *26*, 2602–2610. [[CrossRef](#)] [[PubMed](#)]
42. Floody, P.D.; Navarrete, F.C.; Mayorga, D.J.; Jara, C.C.; Campillo, R.R.; Poblete, A.O.; Alarcón Hormazábal, M.; Thuillier Lepeley, N.; Mansilla, C.S. Efectos de un programa de tratamiento multidisciplinar en obesos mórbidos y obesos con comorbilidades candidatos a cirugía bariátrica. *Nutr. Hosp.* **2015**, *31*, 2011–2016.
43. King, W.C.; Bond, D.S. The importance of pre and postoperative physical activity counseling in bariatric surgery. *Exerc. Sport Sci. Rev.* **2013**, *41*, 26–35. [[CrossRef](#)] [[PubMed](#)]
44. Gadducci, A.V.; de Cleve, R.; de Faria Santarém, G.C.; Silva, P.R.S.; Greve, J.M.D.; Santo, M.A. Muscle strength and body composition in severe obesity. *Clinics* **2017**, *72*, 272–275. [[CrossRef](#)]



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