

Impact of short-term circuit resistance training on women with severe obesity awaiting bariatric surgery: A non-randomized controlled trial

THAURUS CAVALCANTI¹, LUÍS FELIPE DINIZ², BÁRBARA BRUNO SILVA³, CRISTIANO FAUSTINO⁴, PAULO CARVALHO⁵

^{1,2,3,4,5}Post Graduate Program in Surgery – Medical Sciences Center, Federal University of Pernambuco, BRAZIL

Published online: November 30, 2023

(Accepted for publication : November 15, 2023)

DOI:10.7752/jpes.2023.11340

Abstract:

This study aimed to assess the effects of a four-week circuit resistance training (CRT) program, integrated with a multidisciplinary program for bariatric surgery (MPBS), on body weight, body mass index (BMI), functional capacity, and biochemical markers in women with severe obesity awaiting bariatric surgery. A two-arm, non-randomized controlled trial was conducted with fourteen participants enrolled in the MPBS, divided into either the CRT group (n = 8; average age 39.9 ± 13.46 years, BMI = 46.8 ± 9.3 kg.m⁻²) or the control group (CON, n = 6; average age 33.2 ± 5.6 years, BMI = 46.0 ± 6.11 kg.m⁻²) for convenience. The CRT group engaged in eight sessions of circuit resistance training, twice a week for four weeks. At baseline and follow-up, participants were assessed for body weight, BMI, lower limb muscle strength, body balance, flexibility, lipid profile, and fasting glucose. An as-treated analysis was used to address whether the CRT protocol was beneficial if performed. The Analysis of Covariance (ANCOVA) was executed to verify possible between-group differences, with baseline values included as the covariate. At the four week follow-up, the CRT group presented a significant reduction in body weight (CRT: -3.05 [-4.22, -1.89] kg; CON: -0.25 [-2.79, 2.29] kg; p = 0.023), and BMI (CRT: -1.16 [-1.77, -0.75] kg.m⁻²; CON: -0.08 [-1.07, 0.90] kg.m⁻²; p = 0.017) compared with the CON group. The CRT group showed a significant increase in the sit-to-stand test (STS) performance (CRT: +4.38 [3.49, 5.26] reps.; CON: 0.00 [-2.10, 2.10] reps.; p = 0.003). No significant changes were observed in the biochemical markers, body balance, and flexibility within or between groups. Performing four weeks of CRT with a MPBS proved to be a feasible strategy before bariatric surgery, possibly improving body weight, BMI, and lower limb muscle strength for women awaiting BS.

Key Words: bariatric surgery; obesity; circuit-based exercise; physical fitness; weight loss

Introduction

According to data from the World Health Organization (WHO), the rate of obesity has reached epidemic proportions in the past four decades (World Health Organization, 2014). Individuals with obesity are more likely to develop chronic non-communicable diseases, such as diabetes, systemic arterial hypertension, certain types of cancer, sleep apnea, and dyslipidemia, resulting in a higher mortality rate than non-obese individuals (Abdelaal et al., 2017; World Health Organization, 2014). In Brazil, the prevalence of people with severe obesity increased significantly from 1.1% in 2006 to 1.7% in 2017, with a higher prevalence among women than men (0.9% in 2006 and 1.4% in 2017) (Malta et al., 2019).

Bariatric surgery (BS) is indicated for patients with severe obesity [i.e., body mass index (BMI) ≥ 40 kg.m⁻² or BMI ≥ 35 kg.m⁻² with comorbidities] for whom conservative therapy, including behavioral, nutritional, and pharmacological approaches, has failed (Ruban et al., 2019). Surgical treatment has been demonstrated to be an effective alternative for reducing body weight and obesity-related comorbidities, such as diabetes and hypertension, as well as enhancing quality of life, physical fitness, and mental health (Colquitt et al., 2014; Jabbour & Salman, 2021). Despite this, BS cannot be considered as a “silver bullet” to address the severe obesity problem, as it presents several disadvantages (Gualano et al., 2021); for example, people who have undergone BS may experience impairments in their functional capacity due to the significant loss of lean and fat-free mass after surgery, resulting in diminished muscle strength, which may have negative effects on patients' daily activities (Durey et al., 2022; Schurmans et al., 2022). Another negative aspect is that 20% of patients with grade 2 obesity, and 35% of patients with grade 3 obesity, do not achieve the optimal body mass index (BMI) after surgery (Durey et al., 2022). Over time, some of the improvements brought about by BS may be lost, even returning to conditions prior to the surgery, such as weight regain, worsening insulin resistance, compromised endothelial function, and aggravated chronic low-grade inflammation (Gualano et al., 2021; Sakran et al., 2023). In this context, complementary therapies to BS that can mitigate or negate such negative effects are being investigated, among which physical exercise has demonstrated various positive effects in this population (Mechanick et al., 2019; Tabesh et al., 2019).

Since 2001, the Brazilian public healthcare system has provided free BS surgery, with an average wait time of approximately two years (Rasera et al., 2017). During this time, the application of a multidisciplinary program of bariatric surgery (MPBS), which encourages patients to adopt healthy behaviors, has been recommended, since better physical fitness, reduction of body weight, chronic inflammation, and increased insulin sensitivity prior to surgery are associated with improved surgical outcomes, including shorter surgery time and a reduced postoperative hospital stay (Colquitt et al., 2014; Durey et al., 2022; Gilbertson, Gaitán, et al., 2020; Marcon et al., 2017). Similar strategies have been successful in promoting health benefits to people with severe obesity (Lazareva et al., 2017). It has been demonstrated that the integration of a supervised physical exercise program before BS is effective in promoting health improvements in individuals awaiting BS (Baillot et al., 2016, 2018; Gilbertson, Eichner, et al., 2020; Marcon et al., 2017).

Previous studies have shown that strength training is capable of preserving muscle mass in adult individuals undergoing caloric restriction for the purpose of weight loss, a condition similar to that experienced by patients undergoing BS (Kotarsky et al., 2021; Schurmans et al., 2022). Supported by such evidence, the hypothesis has been raised that the inclusion of a strength training program in the period preceding BS may generate a "reserve" of muscle mass to mitigate the subsequent deleterious effect on this variable (Schurmans et al., 2022). Additionally, the inclusion of physical exercise before surgery has proven to be effective in increasing post-surgical physical activity levels (Baillot et al., 2018), which is another crucial aspect in preventing weight regain and maintaining overall health and quality of life. In a study conducted by Gil et al. (2021), it was demonstrated that the implementation of a six-month exercise protocol applied for three months after BS was able to restore muscle mass, muscle strength, and cross-sectional area of type I and II muscle fibers to pre-surgical values, which are results not observed in patients who underwent only the surgery. Whether pre- and post-surgery exercise can prevent the initial loss of muscle mass and strength in patients undergoing BS is a topic that requires further investigation (Schurmans et al., 2022).

In this setting, circuit resistance training (CRT) emerges as an intervention that can provide significant health benefits to BS candidates. CRT consists of executing consecutive exercises that cover different muscle groups with short intervals between them, and with resistance and aerobic training characteristics, providing the benefits of both (Romero-Arenas, 2013). It is a method that optimizes the duration of the session and is simple to implement, as it does not require sophisticated apparatus and machinery, which assists people with obesity in overcoming some perceived barriers to physical exercise (Baillot et al., 2021; Klika & Jordan, 2013). Several health parameters, such as body weight and BMI (Safarzade et al., 2020; Seo et al., 2019), insulin sensitivity (Kolahdouzi et al., 2019; Safarzade et al., 2020), chronic inflammation, and cardiovascular risk (Kolahdouzi et al., 2019), have been improved by the application of CRT in individuals with obesity.

Since there are no guidelines regarding the optimal exercise regimen for patients who are candidates for BS (Durey et al., 2022), investigation into the different exercise modalities is required. Since research into the effects of combining CRT with an MPBS has not yet been conducted (Durey et al., 2022; Schurmans et al., 2022), the aim of the present study was to determine whether four weeks of a supervised CRT in conjunction with MPBS is feasible, and if it improves body weight, BMI, functional capacity, and biochemical markers in women with severe obesity awaiting BS.

Material & methods

Design and Setting

This study used a two-arm, non-randomized, controlled trial design. The research was conducted during January and February 2019 at a referral hospital in BS in a capital city in northeastern Brazil.

Participants

Eligible candidates were adult women awaiting BS. The sample was recruited for convenience and patients were invited to participate in the study during a consultation with the Physical Education Service of the Advanced Laboratory for Physical Education and Health (LAEFES), which is a component of the hospital's MPBS. The research included adult female patients (aged 18 to 60 years) with or without a diagnosis of chronic diseases (diabetes, dyslipidemia, hypertension, and metabolic syndrome), participants of the MPBS, patients with severe obesity, and patients who did not engage in regular physical exercise for three months prior to the beginning of the intervention.

Patients with medical contraindications to physical exercises, functional limitations that prevented the performance of the proposed assessments, pregnant women, and absence on the specified date, time, and location for any of the assessments were excluded from the study. Patients were assigned to the control (CON) or circuit resistance training (CRT) groups after meeting the inclusion criteria and consenting to participate in the study. Prior to the start of the investigation, participants were carefully informed about the risks related to the research, and informed consent was obtained from all individual participants included in the study. This study was approved by the Ethics Committee of the Federal University of Pernambuco (Protocol 3.117.241/19; CAAE 03784818.6.0000.8807).

Procedure

During the intervention, both groups received hospital MPBS. The MPBS included BS medical exams and consultations with doctors, nutritionists, psychologists, speech therapists, social workers, and physical educators. Patients could be in different program phases. In addition to MPBS, the CRT group did two weekly sessions of supervised circuit resistance training on non-consecutive days for four weeks, totaling eight sessions. The circuit consisted of nine strength exercises that utilized machinery and body weight, and that targeted the entire body. The exercises performed in order were the seated bench press, leg extension, seated low row, seated overhead press, isometric pallof press, lat pulldown, bridge exercise, isometric front plank, and sit to stand, with the first exercise changing each session. Each exercise was done for 40 seconds at a regular cadence (about four seconds per repeat) with a 20-second interval between them until all nine were done, marking the end of a series. At each training session, there were four sets. The first set was for warming up, and the others were for the actual workout. There was a two-minute interval between the warm-up set and the next set, and a one-minute rest between the other sets. The intensity utilized was 60% of one repetition maximum (1RM) for machine-based exercises, and body weight for the remainder. The exercises were supervised by physical education specialists with experience supervising resistance training for severely obese patients. Before and after each training session, the patient's blood pressure was measured to ensure their safety.

Materials and instruments

Body weight, BMI, lower limb muscle strength, body balance, flexibility, lipid profile, and fasting glucose were evaluated one week prior to intervention (baseline) and 72 hours after the last training session (follow-up). In the patients' medical records, age and obesity-related comorbidities were identified. Change in body weight was the primary outcome measure. Changes in BMI, biochemical markers, and functional capacity have been set as the secondary outcomes. Body mass and height values were measured with an anthropometric scale (Filizola, São Paulo, Brazil). BMI values were obtained by dividing the body mass value, measured in kilograms, by the square of height, measured in meters, being expressed in kg.m^{-2} .

The CRT group assessed muscle strength in the following exercises using the three to six repetition maximum test (3-6RM): seated bench press, leg extension, lateral pulldown, seated overhead press, and seated low row. The tests were carried out in the sequence specified above, utilizing Matrix Fitness USA (WI, USA) equipment. The acquired results were used to calculate the appropriate load for each participant during the training session. The 3-6RM was chosen because it is more appropriate for inexperienced individuals and has been shown to be highly reproducible in prior studies (Cavalcanti et al., 2022; Moro et al., 2017). Twenty-four to 48 hours prior to the 3-6RM test, participants were familiarized with the exercises and equipment to acclimate them to the test conditions and movement patterns. To perform the test, a specific warm-up was executed for each exercise (12 repetitions with light effort), and then a specific load was specified based on the instructor's experience. This was to ensure that a first attempt at maximum repetitions was performed, and if the number of repetitions exceeded or fell below the range of three to six repetitions, the load was increased or decreased, respectively, until failure occurred within the desired repetition range without compromising the movement pattern. There was a three-minute rest between each trial and between exercises. Brzycki's formula was used to calculate the value of one repetition maximum (1RM) (Brzycki, 1993).

To evaluate the dynamic strength of the lower limbs, a 30-second sit-to-stand (STS) test was administered. The test begins with the subject seated in a chair with a completely supported back, arms crossed in front of the trunk, and knees bent to roughly 90°. At a verbal cue, the participant must rise from her chair and stand upright, and then return to the sitting position, attempting as many repetitions as possible within 30 seconds. Each participant was asked to execute the exercise without moving their arms to rise (Lord et al., 2002). Static body balance was assessed using the monopodal balance test (MBT). The participant would stand barefoot with one leg elevated (knee bent at approximately 90°), having their hands on their hips and their gaze fixed at a point two meters away at eye level. The time the participant remained in this position was timed for up to the maximum limit of 30 seconds. For each lower limb, three attempts were made (Francisco et al., 2009). For data analysis, the value of the best attempt was used.

The measurement of flexibility consisted of performing the sit and reach test (SRT). Each participant was seated on a mat with feet in full contact with the front of the bench, with lower limbs with knees extended, hips flexed, and hands overlapped in front of the body with elbows extended. After correct positioning, each participant was instructed to move the bench scale with their fingertips as much as possible, performing a trunk flexion (Wells & Dillon, 1952). Three attempts were made for each participant, with the obtained value was expressed in centimeters (cm), using the best performance measure for analysis.

Fasting blood samples were obtained at baseline and during follow-up from all participants by a registered nurse after a 12-hour fast. Blood samples were stored at -80°C for subsequent analysis. Blood markers including total cholesterol, triglycerides, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, and glucose were measured with the Architect c8000 analyzer (Abbott, Illinois, U.S.A.).

Data Analysis

The statistical analyses were performed with Jamovi v2.3.21 (available online: <https://www.jamovi.org>). The graphics were constructed with Prism 8.0 (GraphPad Software, La Jolla, CA,

USA). An as-treated analysis was used to address whether the CRT protocol was beneficial if performed. A descriptive analysis was made using means and standard deviation, and absolute and relative frequencies for continuous and categorical variables, respectively. Assumptions were examined using the Shapiro–Wilk test for normality, and Levene’s homogeneity of variance test. Between-group differences at baseline were verified with the Student’s t test.

The Analysis of Covariance (ANCOVA) was performed to verify possible between-group differences, with baseline values included as the covariate. Within-group changes were reported as mean difference with 95% confidence intervals (95% CI). The effect size was calculated using partial Eta squared (η^2p), considering the effect size of 0.01–0.06 as small, 0.06–0.14 as medium, and > 0.14 as large (Lakens, 2013). The significance level was set at $p < 0.05$.

Results

Twenty-four patients satisfied the inclusion criteria and consented to take part in the study. Ten patients were assigned to the CRT group, while fourteen were assigned to the CON group. Two patients in the CRT group were excluded because they did not initiate the intervention program. Eight CON group participants did not return for the follow-up evaluations and were therefore excluded. As a result, fourteen patients completed the trial, with eight in the CRT group and six in the CON group (Figure 1).

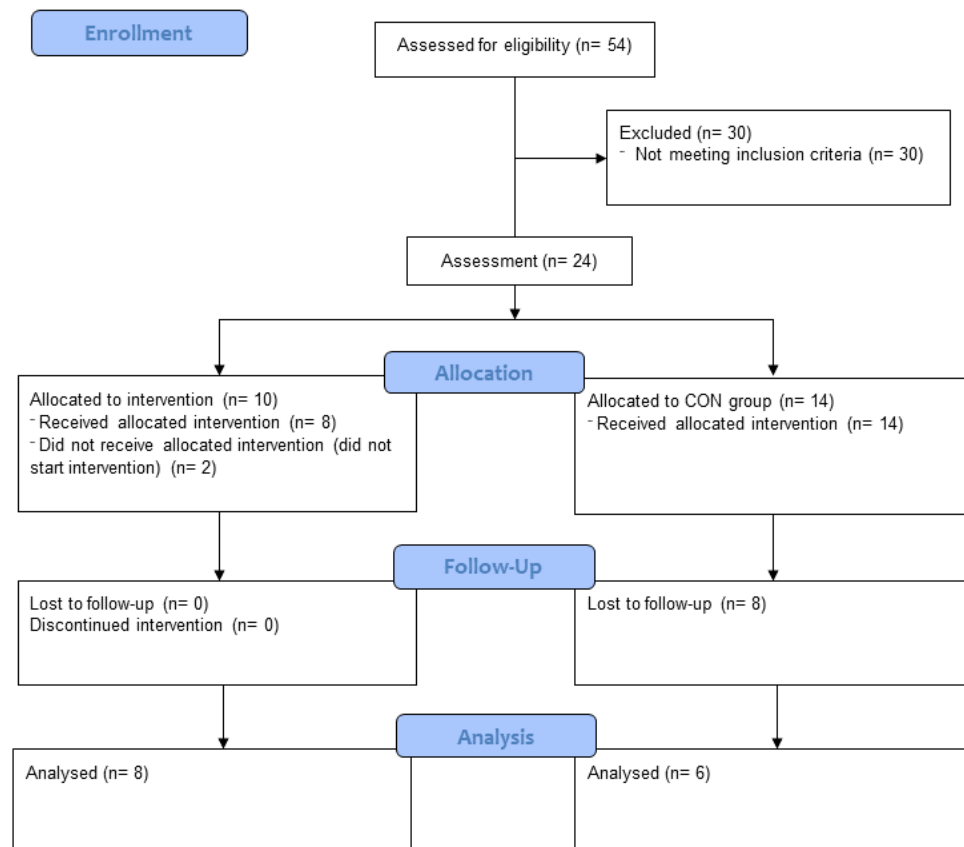


Figure 1: CONSORT (Consolidated Standards of Reporting Trials) flow diagram of participant progression through the study. CRT: circuit resistance training; CON: control.

The characteristics of the participants are shown in Table 1. There were no significant differences between groups in age or BMI at baseline. All participants of the CRT group completed eight training sessions within the designated four weeks, demonstrating satisfactory program adherence. Due to knee discomfort, two participants did not execute the leg extension exercise; instead, they performed a hip extension work on the steppe. Two patients were unable to complete the STR due to positional discomfort, one from each group. Each training session lasted about 45 minutes. No injuries related to training were identified.

Table 1: Participants' baseline characteristics (n=14)

Variable	Circuit (n=8)	Control (n=6)
Age (years), mean (SD)	39.9 (13.46)	33.2 (5.56)
Obesity, n (%)		
Grade 2	3 (37.5)	2 (33.3)
Grade 3	5 (62.5)	4 (66.7)
Comorbidities, n (%)		
SAH	4 (50.0)	2 (33.3)
Type 2 diabetes	2 (25.0)	1 (16.7)
Hepatic steatosis	1 (12.5)	0 (0.0)
Asthma	1 (12.5)	2 (33.3)
Dyslipidemia	1 (12.5)	2 (33.3)
Arthropathy	1 (12.5)	0 (0.0)

SAH: systemic arterial hypertension.

Table 2 displays the within-group changes in body weight, BMI, biochemical markers, and functional capacity at four weeks of follow-up, as well as between-group comparisons and estimated effect sizes.

Table 2: Within- and between-group effects of the anthropometric biochemical markers and functional capacity of the study participants (n = 14)

Variable	Group	Baseline mean (SD)	Follow-up mean (SD)	Within-group change (95% CI)	Between-group effect F	p	η^2p
Body weight (kg)	Circuit (n=8)	115.9 (26.9)	112.9 (27.5)	-3.1 (-4.2, -1.9)	6.94	0.023*	0.387
	Control (n=6)	116.8 (13.5)	116.6 (13.0)	-0.3 (-2.8, 2.3)			
BMI (kg.m ⁻²)	Circuit (n=8)	46.8 (9.3)	45.5 (9.5)	-1.2 (-1.8, -0.8)	7.94	0.017*	0.419
	Control (n=6)	46.0 (6.1)	46.0 (6.2)	-0.08 (-1.1, 0.9)			
Total cholesterol (mg/dl)	Circuit (n=8)	187.8 (52.7)	188.7 (52.4)	0.9 (-16.5, 18.3)	0.29	0.599	0.026
	Control (n=6)	185.8 (36.4)	181.3 (29.4)	-4.5 (-23.3, 14.3)			
HDL (mg/dl)	Circuit (n=8)	47.3 (4.1)	43.9 (4.4)	-3.4 (-7.2, 0.4)	0.17	0.692	0.015
	Control (n=6)	40.7 (3.9)	43.3 (3.3)	2.7 (-2.9, 8.2)			
LDL (mg/dl)	Circuit (n=8)	117.2 (45.4)	118.1 (46.0)	0.9 (-11.7, 13.5)	0.34	0.574	0.03
	Control (n=6)	117.6 (31.6)	113.4 (24.3)	-4.2 (-22.8, 14.4)			
Triglycerides (mg/dl)	Circuit (n=8)	116.4 (54.8)	133.3 (57.2)	16.9 (-1.6, 35.5)	1.57	0.237	0.125
	Control (n=6)	137.8 (54.0)	122.8 (30.2)	-15.0 (-71.9, 41.9)			
Fasting glucose (mg/dl)	Circuit (n=8)	91.7 (21.6)	85.2 (19.1)	-6.5 (-12.5, -0.5)	4.48	0.058	0.289
	Control (n=6)	104.5 (54.8)	102.5 (34.8)	-2.0 (-25.0, 21.0)			
STS (reps.)	Circuit (n=8)	10.0 (1.9)	14.4 (2.1)	4.4 (3.5, 5.3)	15.00	0.003*	0.576
	Control (n=6)	13.3 (3.6)	13.3 (3.2)	0.0 (-2.1, 2.1)			
MBT (s)	Circuit (n=8)	25.1 (9.8)	26.9 (8.8)	1.8 (-1.8, 5.3)	0.24	0.637	0.021
	Control (n=6)	28.3 (4.1)	28.7 (3.3)	0.3 (-0.5, 1.2)			
SRT (cm)	Circuit (n=7)	21.14 (6.84)	24.29 (6.40)	3.14 (0.40, 5.89)	0.155	0.703	0.017
	Control (n=5)	23.54 (8.62)	25.00 (7.58)	1.46 (-6.34, 9.26)			

HDL: high density lipoprotein; LDL: low density lipoprotein; BMI: body mass index; STS: 30 seconds sit to stand test; MBT: monopodal balance test; STR: sit to reach test. * $p < 0.05$.

The biochemical markers studied were total cholesterol ($\Delta\%$: CRT = +1.24% vs. CON = -1.5%), HDL ($\Delta\%$: CRT = -6.94% vs. CON = +7.48%), LDL ($\Delta\%$: CRT = +1.82% vs. CON = +1.69%), triglycerides ($\Delta\%$: CRT = +16.38% vs. CON = -1.97%), and fasting glycemia ($\Delta\%$: CRT = -6.71% vs. CON = +3.32%), and did not show significant differences between groups. The CRT group demonstrated a significant decrease in body weight (Figure 2a; $\Delta\%$: CRT = -2.86 % vs. CON = -0.17 %) and BMI (Figure 2b; $\Delta\%$: CRT = -2.86 % vs. CON = -0.17 %), with a large effect size in both variables, compared to the CON group. The CRT group performed significantly more repetitions in the STS than the CON group (Figure 2c; $\Delta\%$: CRT = +45.29 % vs. CON = +1.85 %), with a large effect size. Between-group performance on the SRT ($\Delta\%$: CRT = +19.78% vs. CON = +10.84%) and MBT ($\Delta\%$: CRT = +16.37% vs. CON = +1.67%) did not differ significantly.

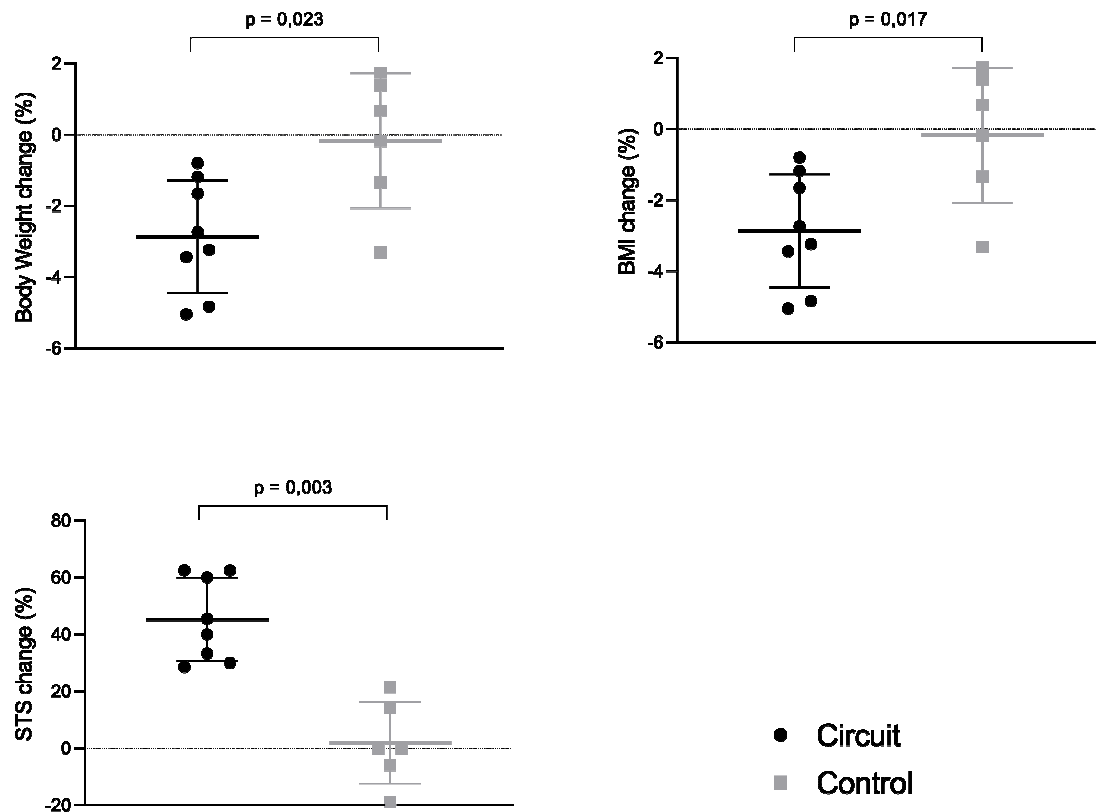


Figure 2: Individual percentage change of the variables (a) body weight, (b) BMI, and (c) sit-to-stand test. The bar represents changes in mean and standard deviation.

Discussion

The incorporation of the CRT in addition to the MPBS was demonstrated to be feasible, given that all the prescribed training sessions were completed without program abandonment or injury report. Gilbertson et al. (2020) conducted a study of people with obesity who were awaiting BS, in which patients were advised to walk at home for 30 minutes, 5 times per week, for 30 days, with adherence monitored by an activity tracker. The researchers reported 18 days of training in total. The high adherence observed in the present study can be attributed to the characteristics of the applied supervised circuit resistance training, namely social interaction, low weekly frequency, training supervision, and reduced session duration. These characteristics contribute to avoiding some known barriers of exercising for people with obesity (Baillot et al., 2021).

There was no significant difference between groups in the values of the biochemical markers analyzed. Kolahdouzi et al. (2019) evaluated the effects of 24 sessions of circuit strength training over the course of 8 weeks in a sample of young men with obesity. The researchers reported a significant improvement in HDL, LDL, total cholesterol, and triglyceride levels. While there was no significant improvement in fasting blood glucose levels, there was a significant improvement in insulin sensitivity. In this regard, Miller et al. (2014) reported significant improvement in total cholesterol and triglyceride levels in a cohort of men with obesity after 4 weeks and a total of 12 training sessions of high-intensity circuit strength training. The intervention applied in the present study was shorter in duration or frequency than those utilized in the aforementioned studies, which may account for these divergent results. Moreover, the investigated population consisted solely of women, which may have affected the biochemical adaptations associated with exercise and weight loss (Romero-Moraleda et al., 2015). Similar results were observed in the study by Marc-Hernández et al. (2019), whose sample consisted predominantly of women who participated in 12 weeks of combined training.

According to a recent review of the literature (Seo et al., 2019), CRT is effective in reducing body weight and BMI in adults, particularly those with overweight or obesity. The results of the present study corroborate these findings. It is important to note that a decrease in body weight is associated with improvements in glucose metabolism and reduced cardiovascular risk in people with obesity (Ryan & Yockey, 2017). Previous

studies have reported benefits in BMI and/or body weight in people with obesity using various exercise strategies; however, compared to the present study, longer periods (Baillot et al., 2016; Marc-Hernández et al., 2019; Picó-Sirvent et al., 2019; Reljic et al., 2020; Safarzade et al., 2020) or higher training intensities (Miller et al., 2014; Reljic et al., 2020) were required. Even with modest training volumes and moderate intensity, CRT appears to be a promising intervention for decreasing the body weight and BMI of women awaiting BS.

The researchers of that study (Kim et al., 2018) proposed static and dynamic flexibility exercises in all 36 training sessions. The absence of exercises aimed to improve flexibility and the short duration of the program potentially justify these results. In regard to postural balance, there was no difference between groups in follow-up. It is worth mentioning that just three patients did not reach maximal score at baseline in the MBT, two for the CRT group, and one for the CON group. These findings agree with previous research (Pataky et al., 2014) that reports no differences in postural balance of women with obesity compared with eutrophic women. Nevertheless, the patients of the CRT group that did not achieve the maximal score in MBT showed substantial improvement in their performance above 60% in test performance (3.18 to 5.2 seconds and 17.92 to 30 seconds). An improvement of this magnitude was seen in the patients of the CON group (20 to 22 seconds), and this improvement is in accordance with recent research that reported better postural balance in people with obesity after six weeks of exercise training.

Women with obesity have a diminished functional capacity compared to eutrophic women, as evidenced by an increased risk of falls, higher metabolic expenditures for walking, and postural alterations, all of which impair the performance of everyday activities (Pataky et al., 2014). It is therefore important to apply therapies that mitigate or ameliorate such functional decreases (Pataky et al., 2014). In the present investigation, only individuals in the CRT group significantly improved on the STS, similar to what Baillot et al. (2016) reported after 12 weeks of combined training administered to patients awaiting BS. This improvement can be attributed to the incorporation of functional exercises designed to simulate patients' daily activities. Regarding flexibility, there were no differences in the performance of the SRT between groups after the intervention. This result diverges from that found by Kim et al. (2018), who subjected 10 university students with obesity to 12 weeks of circuit training and observed a significant improvement in their flexibility. In all 36 training sessions, the researchers recommended both static and dynamic flexibility exercises. Perhaps the lack of flexibility-enhancing activities and the short length of the CRT program applied in the present research underlie these outcomes. There was no difference in postural balance across groups at the follow-up. It is important to note that only three patients did not achieve the maximum score on the MBT at baseline, two in the CRT group, and one in the CON group. These findings are consistent with a previous study that found no difference between the postural balance of people with obesity and those with normal weight (Pataky et al., 2014); however, the patients of the CRT group who did not achieve the maximum score in the MBT showed a substantial increase in their performance above 60% in test performance (3.18 to 5.2 seconds and 17.92 to 30 seconds), while a similar response was not observed in the CON group (20 to 22 seconds). This improvement is consistent with recent research that reported better postural balance in obese individuals after six weeks of exercise training (Cavaggioni et al., 2022).

This study has several limitations that must be considered. First, due to the small sample size, the findings should only be considered exploratory, and further research is required to confirm them. Important confounding variables such as dietary habits, menstrual cycle phase, and sleep disorders were not accounted for; however, this is the first study to apply a CRT program to a sample of women with severe obesity who are candidates for BS. This demonstrated promising results in many health parameters even with short duration, low weekly frequency, and moderate intensity, whereas previous studies reported deterioration in variables related to the health of BS candidates and an increase in the body weight of these patients during the pre-surgical period when only MPBS was followed (Colquitt et al., 2014; Marcon et al., 2017). Future research should employ exercise programs with extended durations to verify adherence and to confirm the maintenance of the benefits observed in this study. It is also necessary to conduct studies to determine whether the pre-surgery exercise-induced beneficial adaptations affect post-surgery outcomes (Durey et al., 2022).

Conclusions

In conclusion, the incorporation of Circuit Resistance Training (CRT) alongside the Multidisciplinary Program of Bariatric Surgery (MPBS) program proved to be feasible, with high adherence and no reported injuries or program abandonment. The success in adherence is attributed to the unique characteristics of supervised CRT, including social interaction, low weekly frequency, training supervision, and reduced session duration, addressing known barriers for individuals with obesity. Although no significant differences were observed in the biochemical markers analyzed, the study demonstrated positive effects on body weight and BMI, aligning with existing literature supporting the effectiveness of CRT in adults, especially those with overweight or obesity. In summary, this study contributes valuable insights into the feasibility and positive effects of integrating CRT into the pre-bariatric surgery (BS) care of women with severe obesity. The promising results pave the way for future research aimed at optimizing exercise interventions to enhance both pre- and post-surgery outcomes in this population.

Conflicts of interest: The authors report that there are no competing interests to declare.

Author contributions: TC, LFD: Project conception, data collection, manuscript draft, and review.

TC: Data analysis.

BBS, CF: Data collection, manuscript draft, and review.

AF, PC: Supervision.

All authors have read and approve the manuscript.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author, TC, upon reasonable request.

References:

- Abdelaal, M., le Roux, C. W., & Docherty, N. G. (2017). Morbidity and mortality associated with obesity. *Annals of Translational Medicine*, 5(7), 161–161. <https://doi.org/10.21037/atm.2017.03.107>
- Baillet, A., Chenail, S., Barros Polita, N., Simoneau, M., Libourel, M., Nazon, E., Riesco, E., Bond, D. S., & Romain, A. J. (2021). Physical activity motives, barriers, and preferences in people with obesity: A systematic review. *PLOS ONE*, 16(6), e0253114. <https://doi.org/10.1371/journal.pone.0253114>
- Baillet, A., Mampuya, W. M., Dionne, I. J., Comeau, E., Méziat-Burdin, A., & Langlois, M.-F. (2016). Impacts of supervised exercise training in addition to interdisciplinary lifestyle management in subjects awaiting bariatric surgery: a randomized controlled study. *Obesity Surgery*, 26(11), 2602–2610. <https://doi.org/10.1007/s11695-016-2153-9>
- Baillet, A., Vallée, C.-A., Mampuya, W. M., Dionne, I. J., Comeau, E., Méziat-Burdin, A., & Langlois, M.-F. (2018). Effects of a pre-surgery supervised exercise training 1 year after bariatric surgery: a randomized controlled study. *Obesity Surgery*, 28(4), 955–962. <https://doi.org/10.1007/s11695-017-2943-8>
- Brzycki, M. (1993). Strength testing—predicting a one-rep max from reps-to-fatigue. *Journal of Physical Education, Recreation & Dance*, 64(1), 88–90. <https://doi.org/10.1080/07303084.1993.10606684>
- Cavaggioni, L., Gilardini, L., Redaelli, G., Croci, M., Cancelli, R., Capodaglio, P., Bruno, A., et al. (2022). A pilot study on attentional focus in prescribing physical exercise in outpatients with obesity. *Healthcare*, 10(11), 2306. <https://doi.org/10.3390/healthcare10112306>
- Cavalcanti, T., De Almeida Diniz, L. F., De Lima, L. F., Amaral Bruno Silva, B., Faustino dos Santos, J. C., Veiga Diniz, M., Barros de Lorena, V. M., et al. (2022). Acute effects of different intensities resistance training on inflammatory markers of women with severe obesity. *Journal of Physical Education*, 33(1). <https://doi.org/10.4025/jphyseduc.v33i1.3358>
- Colquitt, J. L., Pickett, K., Loveman, E., & Frampton, G. K. (2014). Surgery for weight loss in adults. *Cochrane Database of Systematic Reviews*, 2014(10), 244. <https://doi.org/10.1002/14651858.CD003641.pub4>
- Durey, B. J., Fritche, D., Martin, D. S., & Best, L. M. J. (2022). The effect of pre-operative exercise intervention on patient outcomes following bariatric surgery: a systematic review and meta-analysis. *Obesity Surgery*, 32(1), 160–169. <https://doi.org/10.1007/s11695-021-05743-w>
- Francisco, C. O., Okada, V. T., Ricci, N. A., Benze, B. G., Rebelatto, J. R., & Duarte, A. C. G. de O. (2009). Comparação do equilíbrio corporal de mulheres a partir da meia-idade obesas e não-obesas. *Fisioterapia e Pesquisa*, 16(4), 323–328. <https://doi.org/10.1590/S1809-29502009000400007>
- Gil, S., Kirwan, J. P., Murai, I. H., Dantas, W. S., Merege-Filho, C. A. A., Ghosh, S., Shinjo, S. K., et al. (2021). A randomized clinical trial on the effects of exercise on muscle remodelling following bariatric surgery. *Journal of Cachexia, Sarcopenia and Muscle*, 12(6), 1440–1455. <https://doi.org/10.1002/jcsm.12815>
- Gilbertson, N. M., Eichner, N. Z. M., Khurshid, M., Rexrode, E. A., Kranz, S., Weltman, A., Hallowell, P. T., et al. (2020). Impact of pre-operative aerobic exercise on cardiometabolic health and quality of life in patients undergoing bariatric surgery. *Frontiers in Physiology*, 11, 1018. <https://doi.org/10.3389/fphys.2020.01018>
- Gilbertson, N. M., Gaitán, J. M., Osinski, V., Rexrode, E. A., Garmey, J. C., Mehaffey, J. H., Hassinger, T. E., et al. (2020). Pre-operative aerobic exercise on metabolic health and surgical outcomes in patients receiving bariatric surgery: A pilot trial. *PLOS ONE*, 15(10), e0239130. <https://doi.org/10.1371/journal.pone.0239130>
- Gualano, B., Kirwan, J. P., & Roschel, H. (2021). Exercise is key to sustaining metabolic gains after bariatric surgery. *Exercise and Sport Sciences Reviews*, 49(3), 197–204. <https://doi.org/10.1249/JES.0000000000000253>
- Jabbour, G., & Salman, A. (2021). Bariatric surgery in adults with obesity: the impact on performance, metabolism, and health indices. *Obesity Surgery*, 31(4), 1767–1789. <https://doi.org/10.1007/s11695-020-05182-z>
- Kim, J.-W., Ko, Y.-C., Seo, T.-B., & Kim, Y.-P. (2018). Effect of circuit training on body composition, physical fitness, and metabolic syndrome risk factors in obese female college students. *Journal of Exercise Rehabilitation*, 14(3), 460–465. <https://doi.org/10.12965/jer.1836194.097>

- Klika, B., & Jordan, C. (2013). High-intensity circuit training using body weight: Maximum results with minimal investment. *ACSM'S Health & Fitness Journal*, 17(3), 8–13. <https://doi.org/10.1249/FIT.0b013e31828cb1e8>
- Kolahdouzi, S., Baghadam, M., Kani-Golzar, F. A., Saeidi, A., Jabbour, G., Ayadi, A., De Sousa, M., et al. (2019). Progressive circuit resistance training improves inflammatory biomarkers and insulin resistance in obese men. *Physiology & Behavior*, 205(October 2018), 15–21. <https://doi.org/10.1016/j.physbeh.2018.11.033>
- Kotarsky, C. J., Johnson, N. R., Mahoney, S. J., Mitchell, S. L., Schimek, R. L., Stastny, S. N., & Hackney, K. J. (2021). Time-restricted eating and concurrent exercise training reduces fat mass and increases lean mass in overweight and obese adults. *Physiological Reports*, 9(10), 1–17. <https://doi.org/10.14814/phy2.14868>
- Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Frontiers in Psychology*, 4(NOV), 1–12. <https://doi.org/10.3389/fpsyg.2013.00863>
- Lazareva, O., Aravitska, M., Andrieieva, O., Galan, Y., & Dotsyuk, L. (2017). Dynamics of physical activity status in patients with grade I-III obesity in response to a physical rehabilitation program. *Journal of Physical Education and Sport*, 17(3), 1960–1965. <https://doi.org/10.7752/jpes.2017.03193>
- Lord, S. R., Murray, S. M., Chapman, K., Munro, B., & Tiedemann, A. (2002). Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 57(8), M539–M543. <https://doi.org/10.1093/gerona/57.8.M539>
- Malta, D. C., Silva, A. G. da, Tonaco, L. A. B., Freitas, M. I. de F., & Velasquez-Melendez, G. (2019). Tendência temporal da prevalência de obesidade mórbida na população adulta brasileira entre os anos de 2006 e 2017. *Cadernos de Saúde Pública*, 35(9). <https://doi.org/10.1590/0102-311x00223518>
- Marc-Hernández, A., Ruiz-Tovar, J., Aracil, A., Guillén, S., & Moya-Ramón, M. (2019). Impact of exercise on body composition and cardiometabolic risk factors in patients awaiting bariatric surgery. *Obesity Surgery*, 29(12), 3891–3900. <https://doi.org/10.1007/s11695-019-04088-9>
- Marcon, E. R., Baglioni, S., Bittencourt, L., Lopes, C. L. N., Neumann, C. R., & Trindade, M. R. M. (2017). What is the best treatment before bariatric surgery? Exercise, exercise and group therapy, or conventional waiting: a randomized controlled trial. *Obesity Surgery*, 27(3), 763–773. <https://doi.org/10.1007/s11695-016-2365-z>
- Mechanick, J. I., Apovian, C., Brethauer, S., Garvey, W. T., Joffe, A. M., Kim, J., Kushner, R. F., et al. (2019). Clinical practice guidelines for the perioperative nutrition, metabolic, and nonsurgical support of patients undergoing bariatric procedures – 2019 update: Cosponsored by American Association of Clinical Endocrinologists/American College of Endocrinology, The Obesity Society, American Society For Metabolic & Bariatric Surgery, Obesity Medicine Association, and American Society of Anesthesiologists. *Endocrine Practice*, 25(12), 1–75. <https://doi.org/10.4158/GL-2019-0406>
- Miller, M. B., Pearcey, G. E. P., Cahill, F., McCarthy, H., Stratton, S. B. D., Nofall, J. C., Buckle, S., et al. (2014). The effect of a short-term high-intensity circuit training program on work capacity, body composition, and blood profiles in sedentary obese men: A pilot study. *BioMed Research International*, 2014, 1–10. <https://doi.org/10.1155/2014/191797>
- Moro, T., Tinsley, G., Bianco, A., Gottardi, A., Gottardi, G. B., Faggian, D., Plebani, M., et al. (2017). High intensity interval resistance training (HIIRT) in older adults: Effects on body composition, strength, anabolic hormones and blood lipids. *Experimental Gerontology*, 98(August), 91–98. <https://doi.org/10.1016/j.exger.2017.08.015>
- Pataky, Z., Armand, S., Müller-Pinget, S., Golay, A., & Allet, L. (2014). Effects of obesity on functional capacity. *Obesity*, 22(1), 56–62. <https://doi.org/10.1002/oby.20514>
- Picó-Sirvent, I., Aracil-Marco, A., Pastor, D., & Moya-Ramón, M. (2019). Effects of a combined high-intensity interval training and resistance training program in patients awaiting bariatric surgery: A pilot study. *Sports*, 7(3), 72. <https://doi.org/10.3390/sports7030072>
- Rasera, I., Luque, A., Junqueira, S. M., Brasil, N. C., & Andrade, P. C. (2017). Effectiveness and safety of bariatric surgery in the public healthcare system in Brazil: Real-world evidence from a high-volume obesity surgery center. *Obesity Surgery*, 27(2), 536–540. <https://doi.org/10.1007/s11695-016-2439-y>
- Reljic, D., Frenk, F., Herrmann, H. J., Neurath, M. F., & Zopf, Y. (2020). Low-volume high-intensity interval training improves cardiometabolic health, work ability and well-being in severely obese individuals: a randomized-controlled trial sub-study. *Journal of Translational Medicine*, 18(1), 419. <https://doi.org/10.1186/s12967-020-02592-6>
- Romero-Arenas, S. (2013). Impact of resistance circuit training on neuromuscular, cardiorespiratory and body composition adaptations in the elderly. *Aging and Disease*, 04(05), 256–263. <https://doi.org/10.14336/AD.2013.0400256>
- Romero-Moraleda, B., Lozano, A. B. P., Martínez, E. M., López-Plaza, B., Candela, C. G., & Montero, F. J. C. (2015). Lipid profile response to weight loss program in overweight and obese patient is related with

- gender and age. *Nutricion Hospitalaria*, 31(6), 2455–2464. <https://doi.org/https://doi.org/10.3305/nh.2015.31.6.8926>
- Ruban, A., Stoenchev, K., Ashrafi, H., & Teare, J. (2019). Current treatments for obesity. *Clinical Medicine*, 19(3), 205–212. <https://doi.org/10.7861/clinmedicine.19-3-205>
- Ryan, D. H., & Yockey, S. R. (2017). Weight loss and improvement in comorbidity: Differences at 5%, 10%, 15%, and over. *Current Obesity Reports*, 6(2), 187–194. <https://doi.org/10.1007/s13679-017-0262-y>
- Safarzade, A., Alizadeh, H., & Bastani, Z. (2020). The effects of circuit resistance training on plasma progranulin level, insulin resistance and body composition in obese men. *Hormone Molecular Biology and Clinical Investigation*, 41(2). <https://doi.org/10.1515/hmbci-2019-0050>
- Sakran, N., Soifer, K., Hod, K., Sherf-Dagan, S., Soued, S., Kessler, Y., Adelson, D., et al. (2023). Long-term reported outcomes following primary laparoscopic sleeve gastrectomy. *Obesity Surgery*, 33(1), 117–128. <https://doi.org/10.1007/s11695-022-06365-6>
- Schurmans, G., Caty, G., & Reyckers, G. (2022). Is the peri-bariatric surgery exercise program effective in adults with obesity: a systematic review. *Obesity Surgery*, 32(2), 512–535. <https://doi.org/10.1007/s11695-021-05693-3>
- Seo, Y., Noh, H., & Kim, S. Y. (2019). Weight loss effects of circuit training interventions: A systematic review and meta-analysis. *Obesity Reviews*, 20(11), 1642–1650. <https://doi.org/10.1111/obr.12911>
- Tabesh, M. R., Maleklou, F., Ejtehadi, F., & Alizadeh, Z. (2019). Nutrition, physical activity, and prescription of supplements in pre- and post-bariatric surgery patients: a practical guideline. *Obesity Surgery*, 29(10), 3385–3400. <https://doi.org/10.1007/s11695-019-04112-y>
- Wells, K. F., & Dillon, E. K. (1952). The sit and reach—a test of back and leg flexibility. *Research Quarterly. American Association for Health, Physical Education and Recreation*, 23(1), 115–118. <https://doi.org/10.1080/10671188.1952.10761965>
- World Health Organization. (2014). Global status report on noncommunicable diseases 2014. In *Apps. Who. Int. World Health Organization*. https://apps.who.int/iris/bitstream/handle/10665/148114/9789241564854_eng.pdf