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Systematic Review

The Effect of Aerobic and Resistance Exercise after Bariatric Surgery: A Systematic Review

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Abstract: Understanding the optimal time, length, intensity, and type of exercise program for bariatric surgery patients is crucial due to increased obesity prevalence and the number of performed bariatric procedures. Our aim for this review is to identify the effects of exercise on all aspects of health regarding the most recent and randomized studies. A total of 120 articles were reviewed through PubMed. As a result of the research, 11 studies that met the inclusion criteria were included. A quality analysis and a risk of bias assessment of the trials included in this systematic review were performed using the Physiotherapy Evidence Database (PEDro) scoring and classification system. Narrative syntheses were given for this systematic review. The articles' intervention description, outcomes, and results are given in detail in the Results Section. Most exercise interventions were carried out in the post-op stage in bariatric surgery patients. Only two studies were conducted before the scheduled procedure. Overall, aerobic training (AT) and resistance training (RT) combined exercise programs effectively improved clinical parameters, including cardiac function, lower extremity function, muscle strength and endurance, cardiovascular parameters, and functionality. Exercise training caused no additional effects on inflammation and endothelial dysfunction biomarkers. In the literature, no research identifies the effects of only AT on bariatric surgery patients. Therefore, this aspect should be considered when interpreting all the studies' results. In conclusion, there is a need for research to examine only AT in bariatric surgery patients and for general exercise training studies, including better randomization and quality.

Keywords: aerobic training; bariatric surgery; exercise; rehabilitation; resistance training

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1. Introduction

Obesity is a globally prevalent significant public health problem characterized by various alterations in hormonal, inflammatory, and endothelial functions [1–4]. Obesity, typically characterized by a body mass index (BMI) above 30 kg/m^2, increases the likelihood of death from any cause [5]. Given the widespread occurrence of overweight (BMI between 25 and 30 kg/m^2) and obesity, it has become crucial to prioritize interventions such as diet and exercise that encourage weight loss to minimize health risks in the overall population. Obesity stands as a significant, separate risk factor for the emergence of hypertension (HT), type 2 diabetes (DM), and dyslipidemia [6–8]. Prevalence is rapidly increasing worldwide.

Consequently, the search for new methods to treat obesity continues [9]. The amount of energy expended compared to the quantity consumed influences weight changes. As a result, exercise programs and methods for increasing physical activity levels have been used for weight control and loss for a long time. Additionally, several effects of exercise reduce and reverse the damage of obesity. Some of the known advantages of exercise encompass enhancing cardiovascular fitness (CRF) [10,11], managing glucose levels [12,13], improving endothelial function [14,15], influencing lipoprotein particle size [16], boosting high-density lipoprotein [17], and enhancing the overall quality of life. Bariatric surgeries are an accepted weight loss method for patients with morbid and severe obesity [18]. There are various types of bariatric surgeries, including Roux-en-Y gastric bypass (RYGB), sleeve gastrectomy (SG), one anastomosis gastric bypass (OAGB), and biliopancreatic diversion (BPD). SG and RYGB are linked to decreased appetite and decreased brain activity in response to food stimuli. Additionally, the enjoyment of food diminishes, and there is a change in food preference from high-fat and high-sugar options to healthier alternatives, allowing patients to develop a positive eating pattern [19]. At present, bariatric surgery is recognized as the most efficacious approach for treating severe obesity [20]. It demonstrates superior weight loss and the alleviation of obesity-related comorbidities compared to non-surgical interventions [21,22].

Consequently, the number of performed bariatric surgeries has seen a rapid increase. As the number of performed bariatric surgeries increases, the number of pre- and post-op exercise intervention studies increases. Bariatric surgery leads to notable reductions in weight and substantial enhancements in metabolic well-being. Nevertheless, it is not an ideal treatment choice, and its long-term effectiveness remains to be determined. Several studies indicate that a percentage ranging from 10 to 30 of individuals undergoing bariatric surgery encounter less-than-ideal weight loss outcomes [23–25].

The intensity, type, duration, starting point, and protocols of the exercise programs before or after the bariatric surgeries and the effects of different exercise interventions still need to be clearly defined due to scarce research on the subject. Understanding the optimal time, length, intensity, and type of exercise program for bariatric surgery patients is crucial due to increased obesity prevalence and the number of bariatric procedures performed. Our aim for this review is to identify the effects of exercise on all aspects of health regarding the most recent and randomized studies.

2. Methods

2.1. Search Strategy

PRISMA guidelines were used during this systematic review. One researcher in our study group utilized the PubMed database to conduct a literature search in order to find relevant studies. The inclusion criteria for this study encompassed exercise studies involving patients who underwent bariatric surgery, with a publication date from June 2018 to June 2023. The keywords used were "bariatric surgery and exercise" (59), "bariatric surgery and aerobic exercise" (57), "bariatric surgery and resistance exercise" (10), "bariatric surgery and endurance exercise" (4), "gastric bypass surgery and endurance exercise" (1), "gastric bypass surgery and resistance exercise" (7), "gastric bypass surgery and exercise" (26), "sleeve gastrectomy and exercise" (7), "sleeve gastrectomy and aerobic exercise" (6), "sleeve gastrectomy and resistance exercise" (0), "adjustable gastric banding and exercise" (1), "adjustable gastric banding and aerobic exercise" (1), and "adjustable gastric banding and resistance exercise" (0). During the initial search, a total of 120 studies were reviewed.

2.2. Eligibility Criteria

The inclusion criteria for this study were (1) studies that included an exercise program incorporating both aerobic and resistance exercises and (2) studies that had a randomized controlled design. The exclusion criteria for this study were (1) studies for which only an abstract was available and (2) duplicate studies.

2.3. Study Selection and Data Extraction

This systematic literature review incorporated a total of 11 randomized controlled studies. The review provided the following details: first author, publication year, intervention description, evaluation parameters, results, the duration of the intervention, the setting of the intervention, the starting time of the intervention, and PEDro scores (Table 1).

Table 1. Characteristics of the included studies.

Author	PEDro	Follow-Up	Surgery Type	Intervention	Outcomes	Results
Gil et al. (2021) [26]	5	3 months post-op	RYGB	RYGB + ET group (mean age: 38 ± 7, BMI, kg/m^2: 48.9 ± 6.5) AT + RT 3 times per wk. for 6 months AT: 30–60 min treadmill 50% of the delta difference between the ventilatory anaerobic threshold and respiratory compensation point RT: 8–12 reps for major muscle groups RYGB group (mean age: 42 ± 8, BMI, kg/m^2: 47.4 ± 7.6) Usual care	VAT RCP VO_{2peak} MVPA Sedentary Behavior 1-RM Leg Press TUG TST NGP1 ANGP2 TEK VEGF	TUG, BM, 1-RM Leg Press/Bench Press, TST, NGP1, ANGP2, TEK, and VEGF improved significantly in RYGB + ET group
Gil et al. (2021) [27]	5	3 months post-op	RYGB	RYGB + ET group AT + RT 3 times per wk. for 6 months AT: 30–60 min treadmill 50% of the delta difference between the ventilatory anaerobic threshold and respiratory compensation point RT: 8–12 reps for major muscle groups RYGB group Usual care	CR% HRR30s HRR60s HRR120s	CR% (p = 0.04), HRR30s (p = 0.01), HRR60s (p = 0.01) HRR120s (p < 0.01) in the exercised vs. non-exercised group
Tokgoz et al. (2022) [28]	6	3–6 months pre-op		PSADBE + PAC group (mean age: 42.92 ± 5.96, BMI, kg/m^2: 45.75 ± 4.34) 60 min of PSADBE (1–4 wk. at 50–70% of MHR and 4–8 wk. at 60–80% of. MHR) PAC group (mean age: 40.17 ± 10.86, BMI, kg/m^2: 46.39 ± 4.80) Only physical activity counseling	6MWT Biodex System® FSS IWQOL-LITE SST HST InBody270 IPAQ-SF	In PSADBVE 6MWT, Q and H muscle strength in T1–T2, Q and H muscle strength in T1–T3, SCT, SST, and HST scores for T1–T3 and the SCT and SST scores for the comparison of T2–T3, intergroup comparison, the differences in IPAQ scores for comparisons of T1–T2 and T1–T3, SS score for comparisons of T1–T2 and T1–T3, ll comparisons of IWQOL-LITE Total and IWQOL-LITE physical function scores were significantly higher (p < 0.05)

Table 1. *Cont.*

Author	PEDro	Follow-Up	Surgery Type	Intervention	Outcomes	Results
Marc-Hernández et al. (2020) [29]	6	37 months after surgery	Sleeve Gastrectomy	EG group (mean age: 47.3 ± 6.5, BMI, kg/m^2: 38.9 ± 4.8) 20 wks. 2 weekly sessions RT: 0–8 wks. 1 set 20 reps 50–60% RM 8–20 wks.: 4 sets 10–15 reps 65–75% RM ET: HIIT + ACT HIIT: 5–20 wks. 20 min per session (60–95% VO_{2peak}) ACT: 0–4 wks. 35 min 5–20 wks. 50 min (60–80% MHR) CG group (mean age: 43.7 ± 11.4, BMI, kg/m^2: 38.2 ± 5.1) Usual care	SF-36 Total cholesterol Blood glucose Blood pressure Waist/height rt.	EG: blood glucose (p: 0.05), total cholesterol (p: 0.026) after the treatment Between 37 months and 42 months, waist-to-height ratio had significant difference between groups (p = 0.033) Bodily pain (SF-36) decreased in EG (p: 0.044) All body composition aspects improved in EG, except for hip circumference and FFM
Merege-Filho et al. (2023) [30]	6	3 months post-surgery	RYGB	RYGB + ET group (mean age: 41.9 ± 7.2, BMI, kg/m^2: 44.8 ± 4.7) 6 months, 3 times a week RT + AT RT: 3 sets, 8–12 reps AT: 30–60 min RYGB group (mean age: 41.0 ± 7.3, BMI, kg/m^2: 43.6 ± 4.2) Usual care	MRI acquisition FC preprocessing Seed-to-voxel ROI-to-ROI	Seed-to-voxel analyses of hypothalamic connectivity, DMN, pSAL, ROI-to-ROI analyses of brain network connectivity increased significantly in RYGB + ET (p: 0.05). BG network connectivity only increased in RYGB + ET

Table 1. *Cont.*

Author	PEDro	Follow-Up	Surgery Type	Intervention	Outcomes	Results
Asselin et al. (2022) [31]	6	6 weeks post-surgery	Sleeve Gastrectomy or RYGB	PA group (mean age: 39.5 ± 9.4, BMI, kg/m^2: 42.0 ± 4.1) 3 months, 3 times a week RT + AT AT: 3 sets of 10 min at moderate-to-vigorous intensity (60–75% VO_{2peak}) RT: 30 min, large muscle groups Control group (mean age: 38.0 ± 9.6, BMI, kg/m^2: 43.6 ± 5.0) Usual care	VO_{2peak} Blood glucose Lactate Cortisol Testosterone Heart rate Blood pressure	Lack of cortisol increase and lower heart rate were found in the PA group only
Mundbjerg et al. (2018) [32]	6	6 months post-surgery	RYGB	Intervention group 26 weeks, 3 times a week Bike training: 15 min/50–70% VO_{2max}) Resistance training: 10 min/60–75% of 1RM 10–20 rep Optional training: 15 min/50–70% VO_{2max} Control group Physical activity recommendation	VO_{2max} isometric strength dynamometer SST SCT	In INT group VO_{2max}, hip MS, SST, and SCT improved significantly
Auclair et al. (2021) [33]	8	3 months post-surgery	Biliopancreatic diversion or Sleeve Gastrectomy	EG group 3 months, 3 times a week AT: 35 min/60–75% of VO_{2max} RT: 25 min/large muscle groups, 3 sets, 10–12 reps CG group Physical activity advice	VO_{2peak} LVDD	Exercise did not have additional impact on weight, FM, or FFM İn EG VO_{2peak} increased significantly versus CG

Table 1. *Cont.*

Author	PEDro	Follow-Up	Surgery Type	Intervention	Outcomes	Results
Stolberg et al. (2018) [34]	6	6 months post-surgery	RYGB	Intervention group 26 weeks, 2 times a week Moderate intensity endurance and resistance training CON(*n*: 28) Physical activity advice	CRP ICAM-1 IL-6 t-PA:Ag vWF	Exercise caused no additional improvements
Júnior et al. (2021) [35]	6	3 months post-surgery	RYGB	HB group (mean age: 47.5 ± 11.6, sex: F 84.8%/M 15.2%, BMI, kg/m^2: 36.0 ± 6.8) 3 months, 3 times a week, semi-supervised AT: 6–8 RPE, 30–50 min (walking, jogging, stair climbing) RT: 6–8 RPE, 4–5 × 10–15 Control group (mean age: 47.3 ±10.9, sex: F 83.8%/M 16.2%, BMI, kg/m^2: 35.3 ± 6.7) No intervention	Waist circumference Hip circumference Weight BMI Handgrip strength TST−30 s VO_2 TC (mg dL) LDL, HDL, TG Fasting glucose Fasting insulin HbA1c (%) C−Peptide (ng/mL) CRP, SBP, DBP	Waist circumference did not change within or between groups ($p > 0.05$) HB group TST (p: 0.02) and VO_{2max} (p: 0.04) improved when compared with CTRL
Stolberg et al. (2018) [36]	6	6 months post-surgery	RYGB	Intervention group (mean age: 42.4 ± 9, BMI, kg/m^2: 33.3 ± 6.2) 26 weeks, 2 times a week Moderate intensity endurance and resistance training Control group (mean age: 42.3 ± 9.1, BMI, kg/m^2: 34.1 ± 5.4) Physical activity advice	Self-reported PA RPAQ) Objective PA ACC HRQoL	The SF-36 domain "general health" increased in INT compared to CON 24 months after RYGB ($p = 0.041$)

RYGB: Roux-en-Y gastric bypass, ET: exercise training, AT: aerobic training, RT: resistance training, VAT: ventilatory anaerobic, MVPA: moderate-to-vigorous physical activity threshold, TUG: Timed Up-and-Go Test, 6MWT: 6 min walking test, TC: total cholesterol, HRQoL: Health-Related Quality Of Life, CRP: c-reactive protein, t-PA:Ag: tissue-type plasminogen activator antigen, vWF: von Willebrand factor, LVDD: Left Ventricular Diastolic Dysfunction, SST: Sit-to-Stand test, TG: total glucose, BMI: body mass index, SCT: Stair Climb Test, FC: functional connectivity, HRR30-60-120: HR after 30, 60, and 120 s of recovery in relation to HRpeak, MS: muscle strength, DMN: default mode network.

The datasets containing the independent searches of two researchers were imported into Rayyan (QCRI, Qatar) software. Rayyan is a practical and automated article management tool for systematic reviews. With this software, duplicate records can be detected automatically. However, it is possible to manually mark the inclusion of trials in the review with "yes", "no", and "maybe" commands on the title/summary.

The two investigators who performed the screening evaluated the trials' eligibility by considering the studies' inclusion/exclusion criteria through the Rayyan software. When two investigators disagreed on trial selection, a consensus was reached by considering the opinion of an academician who is an expert in surgical rehabilitation and knowledgeable about the systematic review methodology. A PRISMA flowchart of this systematic review is presented in Figure 1.

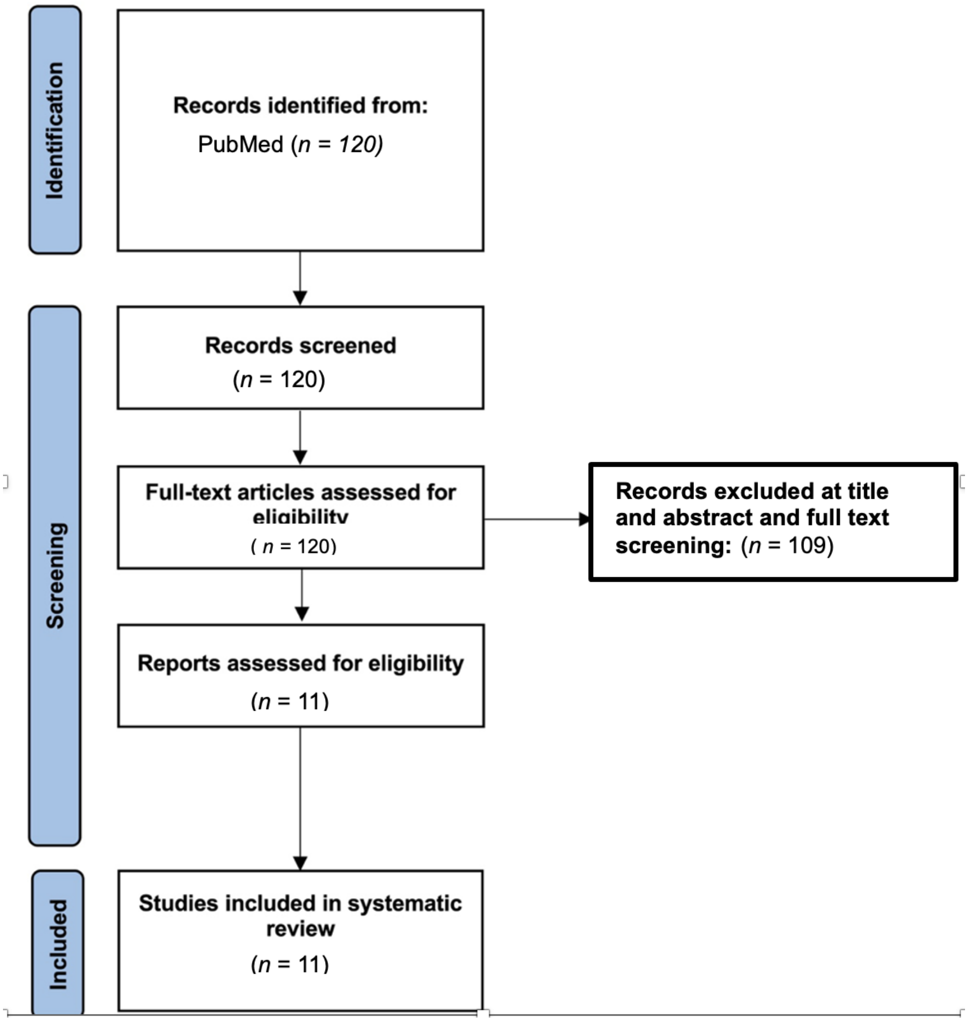

Figure 1. PRISMA flow diagram of the study.

2.4. Quality and Risk of Bias Assessment

Two independent reviewers conducted quality assessments using PEDro scores. In case of any disagreements, a third researcher was consulted. PEDro comprises 11 questions that evaluate specific aspects, such as eligibility criteria, randomization, blinding, follow-up procedures, and analysis methods. Each item in PEDro is answered with either a "Yes" or a "No." The scores obtained from PEDro categorize the quality of the study as "excellent" for 9–10, "good" for 6–8, "moderate" for 4–5, and "poor" for 0–3.

2.5. Evidence Synthesis

The review results are presented, displaying the principles of narrative synthesis. The procedures of "developing a preliminary synthesis, exploring relationships within and between studies, and determining the synthesis's robustness" were regarded during the synthesis. Then, the results are shown, displaying the qualitative and quantitative characteristics of the trials. The authors state that this systematic review protocol was not registered.

3. Results

3.1. Quality Analysis and Risk of Bias Results

Only one study did not specify the exclusion and inclusion criteria, while the other ten described these criteria. Random allocation was described in all of the studies according to our inclusion criteria. Only two studies described blinding in assessors. In the case of considering "PEDro scores" for included articles, only one article was "moderate", and ten articles had a "good" level of evidence. A high majority of the trials had scores of 6–8. The trials' mean "PEDro score" was 6.18 ± 0.75 (min–max 5–8). According to the mean PEDro score, the absolute classification of the articles is "good" (Table 2).

Table 2. PEDro scores of the trials.

Article	Q-1	Q-2	Q-3	Q-4	Q-5	Q-6	Q-7	Q-8	Q-9	Q-10	Q-11	Total
Gil et al. (2021) [24]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	7
Gil et al. (2021) [25]	Y	Y	N	N	N	N	N	Y	N	Y	Y	5
Tokgoz et al. (2022) [26]	Y	Y	N	N	N	N	Y	Y	N	Y	Y	6
Marc-Hernández et al. (2020) [27]	N	Y	N	Y	N	N	N	Y	N	Y	Y	6
Merege-Filho et al. (2023) [28]	Y	Y	N	N	N	N	N	Y	Y	Y	Y	6
Asselin et al. (2022) [29]	Y	Y	N	Y	N	N	N	Y	N	Y	Y	6
Mundbjerg et al. (2018) [30]	Y	Y	N	Y	N	N	N	N	Y	Y	Y	6
Auclair et al. (2021) [31]	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	8
Stolberg et al. (2018) [32]	Y	Y	N	Y	N	N	N	N	Y	Y	Y	6
Júnior et al. (2021) [33]	Y	Y	N	Y	N	N	N	N	Y	Y	Y	6
Stolberg et al. (2018) [34]	Y	Y	N	Y	N	N	N	N	Y	Y	Y	6

Q-1: eligibility criteria; Q-2: random allocation; Q-3: concealed allocation; Q-4: baseline comparability; Q-5: blind subjects; Q-6: blind therapists; Q-7: blind assessors; Q-8: adequate follow-up; Q-9: intention-to-treat analysis; Q-10: between-group comparisons; Q-11: point estimates and variability, median values (item total score), and item score (yes/no).

3.2. Muscle Re-Modeling after Bariatric Surgery

Gill et al. evaluated muscle functionality and strength in bariatric surgery patients three months after the surgery. The results are in line with those in the literature. After the bariatric surgery, the participants' lower- and upper-limb muscle strength significantly decreased. The authors conducted an exercise program involving aerobic and resistance exercises in three sessions per week for six months. The aerobic training regimen involved 30 to 60 min of treadmill walking, with a progressive increase of 10 min every four weeks. The exercise intensity was 50% of the difference between the ventilatory anaerobic threshold and respiratory compensation point. During each session, heart rate was continuously monitored using Polar® to maintain the appropriate exercise intensity. The resistance exercise protocol comprised three sets of 8–12 repetition maximum for major muscle groups. At the end of the 6 months, the intervention group showed improved capillarization and satellite cell content, greater muscle strength, and better scores in functionality tests (TUG and TST) [26].

3.3. Cardiac Function

Gill et al. investigated exercise's effects on cardiac function in post-bariatric surgery patients. After 6 months, the exercise intervention group's HRR60s as well as HRR120s were significantly higher than control group. They exhibited a lower occurrence of blunted heart rate recovery (HRR) than the group that did not participate in the exercise. The findings of this study suggest that exercise training, when combined with bariatric surgery, has an additional positive impact on cardiac recovery percentage (CR%) and heart rate recovery (HRR). These improvements indicate an enhanced regulation of cardiac autonomic function in women following bariatric surgery [27].

3.4. Lower Extremity Function

A different approach was performed by Tokgoz et al. Their randomized trial researched the effects of a pre-surgical aerobic dance-based exercise program (PSADBE). The researchers also provided physical activity counseling for the control and the intervention groups. The exercise intensity calculation was performed with MHR and progressively increased after four weeks. Participants followed the PSADBE program for eight weeks with two sessions per week. During the assessment sessions, a six-minute walk test, a Stair Climbing Up–Down Test, an Isokinetic Test, PA level measurements, fatigue measurements, and QoL measurements were conducted. Statistically significant improvements were observed in functional capacity, muscle strength and endurance, physical activity (PA), and fatigue scores after treatment and in the fifth month post-surgery in Group I ($p < 0.05$) [28].

3.5. Weight Control after Bariatric Surgery

The efficacy of bariatric surgery in promoting weight loss has been extensively demonstrated. However, its impact weakens over time, and weight regain is one of the most seen complications among individuals who undergo bariatric procedures [37]. To the best of our knowledge, exercise is one of the most effective ways to provide and maintain weight control with various mechanisms [38]. In the study by Marc-Hernández et al., persons who had undergone bariatric surgery three years prior were enrolled and followed a 5-month combined exercise training program. The program included both HIIT and resistance exercises for big muscle groups of the body. HIIT appears to be crucial due to its ability to induce a greater glucose uptake than low- or moderate-intensity training. This is due to its various effects on parameters related to cardiovascular risk being highly significant [39]. Additionally, a recent study showed that HIIT in both interval and continuous modalities produced higher levels of irisin secretion, which is a myokine that participates in energy expenditure, transforming white adipose tissue (WAT) to brown adipose tissue (BAT) [40]. After five months of exercise training, there were significant decreases in fat mass and fat mass percentage and a tendency towards overall weight reduction. Additionally, there was an increase in the percentage of excess weight loss (%EWL) and fat-free mass (FFM) in the exercise group (EG) upon the completion of the exercise program.

3.6. Hypothalamic Connectivity and Brain Functional Networks

A compelling study of patients who underwent bariatric procedures showed that the functional connectivity (FC) between brain regions associated with emotional control and social cognition experienced a temporary decline after treatment initiation. However, after one year of follow-up, the participants showed subsequent improvement and returned to baseline levels [41]. Merege-Filho et al. researched the effects of exercise on hypothalamic connectivity and functional brain networks in women who had undergone bariatric procedures. The RYGB + ET group received a six-month, three-times-a-week exercise program involving resistance exercises and aerobic training (30–60 min). The findings indicated that the exercised patients exhibited enhanced connectivity between the hypothalamus and various regions associated with sensory and visual integration compared to the non-exercised patients. Furthermore, exercise following surgery impacted the medial hypothalamic nucleus, which plays a role in suppressing appetite and increasing energy expenditure. These results suggest that exercise could serve as a valuable tool to enhance the central regulation of food intake in women who have undergone bariatric surgery. Another critical point is the basal ganglia, consisting of a group of nuclei within the reward circuitry, which is believed to regulate the equilibrium between reward and inhibitory control. This study also showed that only bariatric surgery is ineffective in reversing the decreased connectivity in this network, whilst exercise and surgery increased BG connectivity.

3.7. Cortisol and Testosterone Response

Cortisol plays a significant role in various metabolic pathways, particularly impacting blood glucose levels by mobilizing amino acids and converting them into glucose and glycogen through gluconeogenesis. Exercise at high intensities is a physiological stressor, and cortisol levels increase alongside heart rate and blood lactate levels in lean, healthy individuals. Obesity affects the normal function of metabolic and hormonal systems. As a result, in patients with obesity, the cortisol response to exercise may be greater than that in healthy persons, which can induce skeletal muscle protein catabolism [42]. Asselin et al. studied post-bariatric surgery patients six weeks after the procedure and enrolled the participants in three months of exercise training. The study's exercise program involved three weekly sessions of aerobic (30 min) and resistance (30 min) training. The post-intervention results indicated that three months of resistance and aerobic training could decrease exercise heart rate and exercise-induced increase cortisol release, while testosterone levels remained unchanged.

3.8. Aerobic Capacity

Before any bariatric surgery, bariatric patients are less physically active than healthy lean controls. Less than 5% of bariatric surgery candidates meet the physical activity guidelines of ACSM (American College of Sports Medicine) [43]. This population has a lower aerobic capacity than healthy lean controls. Weight loss achieved through caloric restriction, whether through hypocaloric diets or bariatric surgery, decreases muscle mass and muscle strength (MS) without improving aerobic capacity if not accompanied by physical training. Our review shows that combined exercise training increases aerobic capacity and a person's tolerability of exercise in hormonal and cardiac response aspects.

3.9. Inflammation

Obesity is characterized by the excessive accumulation of body fat in white adipose tissue (WAT), which acts as an active endocrine organ that produces and releases various cytokines, including the pro-inflammatory mediator Interleukin 6 (IL-6). These cytokines cause the release of molecules that induce endothelial dysfunction (CRP, vWF, ICAM-1, and t-PA:Ag). The study conducted by Stolberg et al. investigated the effects of a 26-week AT and RT combined exercise program on biomarkers of inflammation and endothelial dysfunction in post-bariatric surgery patients. As a result, no significant correlations were discovered between the changes in weight or BMI and the alterations in markers associated with inflammation and endothelial function, except for a negative correlation between the change in vWF and the changes in weight and BMI. The study also revealed no effects of supervised physical training on markers of inflammation or endothelial function ($p > 0.05$ for all parameters).

4. Discussion

This systematic review purposed to document the effects of exercise in people who underwent or were scheduled for bariatric surgery procedures. Obesity is a health problem affecting a person's metabolic status, cardiac functions, aerobic capacity, and risk of other comorbidities. While obesity in the worldwide population is on the rise, strategies for treatment options are increasing. The most recent and one of the most used strategies is bariatric procedures. Bariatric procedures regulate metabolic function and help with weight loss [42]. After the surgeries, some patients may not reach the optimal weight loss or, in time, experience weight regains [36]. Exercise is a critical factor in determining overall daily energy expenditure, making it crucial in influencing energy balance. This impact has been demonstrated in several long-term studies [44,45]. At this time, exercise can help people to reach optimal weight loss, maintain weight control, decrease the risk of compilations of surgeries, and present various health benefits. Our review examined 11 articles that align with our inclusion criteria. One of these articles included a study conducted in the pre-op stage [27], while other procedures were carried out in the post-op patients.

All the studies showed that an exercise program, including AT and RT, plays a significant role in people's cardiovascular function, functional status, muscle strength, decreased hypothalamic connectivity, and brain functional networks. These results are in line with those in the recent literature. Exercise enhances cardiovascular well-being through various mechanisms, such as promoting the generation of more mitochondria and increasing the oxidation of fatty acids. This issue leads to the dilation of blood vessels, ultimately resulting in improved perfusion of the heart muscle. These effects have been supported by several high-quality studies [46,47]. The physiological changes that occur in response to aerobic and resistance exercise are unique: aerobic exercise enhances cardiovascular adaptations that elevate maximum oxygen intake without substantially affecting strength, while resistance exercise enhances neuromuscular adaptations that increase strength without significantly impacting maximum oxygen intake [48].In both Villareal et al. and Dennis et al. studies showed that the combined use of aerobic training (AT) and resistance training (RT) is the most effective for weight loss in older adults with obesity [49,50]. In a fascinating study in our review, researchers showed that the exercise program increased the connectivity between brain regions associated with emotional control and social cognition [29]. These results are significant, considering that a recent report observed that these functional connections decreased after bariatric surgery. This aspect of exercise treatment in these populations can decrease appetite and regulate overeating. In the literature, no research was conducted on only AT in subjects in the pre-op or post-op stage. So, we can only interpret AT and RT combined treatment. Future studies should assess the effects of only AT on bariatric surgery patients because, in combined studies, it needs to be made clear which strategies caused the concluded effects—recognizing the constraints of a review that analyzes a diverse range of studies. Another limitation of our review is that most articles had low attendance rates. This situation may lower the quality of the result. In general, the primary and secondary outcomes of the reviewed articles were very diverse. This variety of output has advantages and disadvantages for our review.

Different outcomes, procedures, and aims of studies allow our review to examine the effects of exercise on bariatric patients in all aspects. As a strength of our review, our researchers included randomized control trial articles only written in the last five years due to our preference for utilizing high-quality work. Overall, the number of good-quality studies on the topic is still being determined. Cardiovascular fitness was only investigated in five of the reviewed articles. Three of these five articles found that AT and RT combined exercise therapy effectively increases VO_2 max [32,34,43]. Although this review provides evidence supporting the inclusion of exercise in the post-operative care of bariatric surgery patients, there is still a need to determine the ideal intensity, duration, length, and specific type of exercise. Four of the eleven reviewed studies examined the effects of exercise on functional status in these patients, and all of these articles concluded that combined exercise increases functional status. Other aspects of a person's general status have not yet been identified.

When examining the results of the studies included in our review, the practical implications drawn indicate that exercise, regardless of the type of bariatric procedure (SG, RYGB, or BPD), does not pose complications and is safe when implemented before or after surgery. Exercise can be used and is effective in increasing weight loss, preventing weight regain, improving an individual's cardiovascular functions, and regulating the exercise response following a bariatric procedure. When exercise is implemented before the procedure, it improves the individual's functional status following surgery. Due to the variations in exercise methods, durations, and frequencies across the studies, we cannot provide a specific, effective program.

There are some limitations to our study. In the literature, there are only 11 randomized controlled studies investigating the effects of AT and RT on bariatric surgery patients, and most of these studies were conducted with a minimal number of participants. In 3 out of the 11 included studies, separately, the age, BMI means, and sex ratio of the groups were not provided. Two of these studies did not specify the type of bariatric surgery performed on the patients. When we looked at the quality of the studies in terms of bias, none of the included studies conducted evaluator, therapist, or patient blinding. As mentioned above, the interventions applied to the participants and the outcome measures varied significantly across the studies. This issue can be considered another limitation of the research. The absence of all these factors makes interpreting and applying the results to practice challenging.

5. Conclusions

In the literature, there were 11 randomized studies investigating the effects of concurrent exercise therapy with both AT and RT on patients with obesity who underwent or were scheduled for bariatric procedures in line with our inclusion criteria. Most exercise interventions were carried out in the post-op stage in bariatric surgery patients. Only two studies were conducted before the scheduled procedure. Overall, AT and RT combined exercise programs effectively improved clinical parameters, including cardiac function, lower extremity function, muscle strength and endurance, cardiovascular parameters, and functionality. Exercise training caused no additional effects on inflammation and endothelial dysfunction biomarkers. In the recent literature, no research identifies the effects of only AT on bariatric surgery patients. Therefore, this aspect should be considered when interpreting all the studies' results. In conclusion, future research needs to investigate the effects of only AT on bariatric surgery patients. Moreover, there is a need for more high-quality research involving randomization and blinding with a high number of participants for determining the exercise intensity and duration of AT for these patients both post- and pre-surgery. In addition, there was only one study conducted in the pre-op stage. It is difficult to clearly state the long-term outcomes following exercise in this group of patients when it is applied during the preoperative period. Therefore, increasing the number of exercise studies conducted during the pre-operative period is necessary to better understand the long-term results.

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