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BRIEF COMMUNICATION

Exercise Training Does Improve Cardiorespiratory Fitness in Post-Bariatric Surgery Patients

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Abstract

Although exercise is recognized as an important component of the management for patients following bariatric surgery (BS), its effectiveness on cardiorespiratory fitness (CRF) is still unclear. To investigate this relationship between BS and CRF, a systematic review was conducted in the MEDLINE database. The literature search included studies involving exercise training in patients following BS. A total of 306 studies were identified, 7 met the criteria and were included in the meta-analysis. Exercise training was found to result in a moderate and significant increase in VO_2max (SMD = 0.430, 95% CI 0.157; 0.704, $p = 0.002$) following BS. The results from this meta-analysis indicate that exercise training can significantly improve CRF. Further research is needed to determine the ideal training duration and exercise training parameters for patients following BS.

Keywords Bariatric surgery · Exercise training · Cardiorespiratory fitness

Introduction

Bariatric surgery (BS) has been considered superior to both medical therapy and intensive lifestyle interventions to achieve significant and long-lasting weight loss in obese individuals [1]. BS has also been shown to restore the ability to perform activities of daily living in obese individuals [2]. Exercise training following bariatric surgery can provide additional benefits in the obese population (i.e., increase maximum oxygen consumption (VO_2max) and greater improvements in skeletal muscle metabolism) and has also been shown to be an efficient additional intervention to increase cardiorespiratory fitness in post-BS patients [3].

Although, a few studies show VO_2max increase after aerobic and/or resistance training in post-BS patients [4, 5], other studies failed to show an additive effect of exercise training on exercise capacity compared to BS alone [6, 7]. This inconsistency could be due to the lack of standardization among exercise training protocols, cardiorespiratory fitness testing procedures, time to start intervention post-BS, intervention duration, lack of statistical power, or other methodological differences such as assessment of VO_2max in absolute or relative values. Therefore, our goal was to perform a meta-analysis in order to determine the effect size of exercise training (aerobic, resistance, or both) on VO_2max in adults following bariatric surgery weight loss.

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Methods

Data Sources and Searches

The search was conducted on studies published prior to August 21, 2018 in the MEDLINE database (through PubMed), using the following terms: "Bariatric Surgery" OR "Metabolic Surgery" OR "Bariatric Surgeries" AND "exercise" and included clinical studies, clinical trial, comparative studies, multicenter studies, observational studies, and randomized controlled trials.

Study Selection

For the meta-analysis, we considered all eligible prospective cohort models, human subjects (adults over 19 years old), written in English language, studies investigating the association between CRF and measured cardiorespiratory variables following BS by cardiopulmonary exercise testing, and studies which included a description of the exercise training protocol. Exclusion criteria: non-original publications (i.e., errata, letters to the editor, reviews), retracted papers, guidelines, qualitative studies, lack of an exercise training intervention (aerobic, resistance, or combined), and studies which did not investigate the effects of exercise training on VO_2max. Two reviewers (AG and AS) independently screened all titles and abstracts for eligibility. Any disagreements about inclusion of studies were resolved by discussion.

Data Extraction and Statistical Analysis

The average, standard deviation, and sample size of VO_2max following BS at baseline and post-intervention in exercise training groups and control groups (CG) were extracted from each study. The meta-analysis was performed using comprehensive meta-analysis software version 3.3.070. The effect size was calculated based on the standardized mean difference (SMD) of the change in VO2max (baseline to post-intervention) between exercise training groups and CG. The quality of studies was assessed using the PEDro scale (0–10). Heterogeneity of studies was assessed using I^2 ($p = 0.05$). The risk of publication bias was assessed by Egger's test ($p = 0.05$).

Results

Description of Included and Excluded Studies

From 306 studies found in the first search, only 7 randomized control trials (RCTs) were met the criteria for inclusion. Descriptions of included study characteristics are described in Table 1. The studies that did not met the criteria included an erratum ($n = 1$); a retracted paper ($n = 1$); review papers ($n = 106$); letters to the editor ($n = 9$); other non-original studies ($n = 13$); guidelines ($n = 7$); qualitative studies ($n = 5$); studies with children ($n = 2$); no exercise effects on VO_2max ($n = 151$); no aerobic, resistance, or combined training intervention ($n = 3$); and study without extracted data ($n = 1$).

Quality of the Studies and Publication Bias

Among the seven studies selected, three studies scored 4 [6, 8, 10], one study scored a 6 [4], and other three studies scored 7 [3, 5, 7] on the PEDro scale. Two questions regarding blinding patient and care provides were nulled as it is not possible in exercise intervention RCTs. The p value for Egger's test was 0.25, suggesting no risk of publication bias. Since there was no statistical significance for heterogeneity ($I^2 = 0.0\%$, $p = 0.76$), fixed effect models were selected for all analysis.

Outcomes

The pooled results of these studies demonstrate that exercise training leads to a moderate and significant increase of VO_2max in post-BS patients (SMD = 0.430, 95% CI 0.157; 0.704, $p = 0.002$) (Fig. 1).

Discussion

The results of this meta-analysis demonstrate that exercise training following BS results in a moderate increase in VO_2max following BS. This suggests an important risk reduction effect of exercise in this population when considering that CRF is inversely correlated with mortality. Increasing CRF by 1 MET (3.5 ml/kg/min) is associated with a 10 to 12% of reduction in mortality rate independent of disease status [9, 11]. An isolated meta-analysis analysis with a subgroup of 5 studies measuring relative VO_2max showed that exercise training following BS results in a raw mean increase of 0.73 ml/kg/min (95% CI 0.0; 1.47) [3, 5–7, 10].

Following BS, patients undergo substantial and immediate weight loss and tend to become more physically active which may increase VO_2max [10, 12]. The increase in relative VO_2max could be due to reduction in body weight, as confirmed by the VO_2max increase in the CG (Table 1). In this context, it is very important to isolate the effect of the exercise on VO_2max from the weight loss effects on exercise capacity [10]. In this study, we were not able to completely eliminate this confounding factor (the majority of the studies included did not provide

Table 1 Characteristics of included studies in the meta-analysis

First author, year	ET: *n* and sex, mean age (years); (CG)	Surgery	ET protocol: time from surgery to start exercise; exercise type; exercise load; frequency (day/week); session duration; training duration	Baseline Weight (kg) or BMI (kg/m^2)	Mean of the body weight loss (kg)	VO_2max (ml/min) or (ml/kg/min)
Coen 2015 [4]	ET *n* = 50, 44 W; 41.6 ± 9.3 CG *n* = 51, 43 W, 42.1 ± 9.9	RGYBP	2.57 ± 0.8 months; aerobic; 60 to 70% maxHR; 3.5 ± 1.2×/week; 44 ± 14.1 min; 06 months	ET 108.2 ± 20.2 kg CG 106.8 ± 25.4 kg	ET − 23.6 kg (CG − 22.1 kg)	ET: Pre (1955.3 ± 429.3 ml/min); Post (2068.7 ± 609 ml/min) CG: Pre (1935.3 ± 468.1 ml/min); Post (1859.8 ± 552.2 ml/min)
Huck 2015 [7]	ET *n* = 07, 06 W; 53.6 ± 8.2 CG *n* = 08, 06 W, 44.0 ± 9.7	RGYBP and LAP-Band	4.3 ± 1.7 months; resistance; 60 to 75% 1RM; 2–3×/week, 60 min; 03 months	ET 101.6 6 19.8 kg CG 92.5 ± 5.5 kg	ET − 8.8 kg (CG − 5.6 kg)	ET: Δ post−pre (0.91 ± 0.81 ml/kg/min) CG: Δ post−pre (0.46 ± 0.97 ml/kg/min)
Nunez Lopez 2017 [8]	ET *n* = 11, 09 W; 43.0 (36.7–49.3) CG *n* = 11, 09 W, 38.5 (30.3–46.6)	RGYBP	76.7 (59.1–94.4) days; aerobic; 60 to 70% maxHR; 3.5 ± 1.2×/week; 44 ± 14.1 min; 06 months	ET 106.9 (97.0–116.9) kg CG 101.1 (100.4–121.7) kg	ET − 25.0 kg CG − 22.1 kg	ET: Pre (2200; CI 2000 to 2400 ml/min); Post (2400; CI 2200 to 2400 ml/min) CG: Pre (2100; CI 1700 to 2400 ml/min); Post (2100; CI 1700 to 2400 ml/min)
Marchesi 2015 [5]	ET *n* = 07, 07 W; 43.1 (37–48) CG n = 10 W, 39.1 (31–49)	RGYBP	19 (12–31) months; aerobic; 60–70% and 70–90% maxHR; 3×/week; 60 min; 10 months	ET 29.3 (23.9–33.6) kg/m^2 CG 30.1 (25.9–39.3) kg/m^2	ET − 2.2 kg/m^2 (CG − 0.3 kg/m^2)	ET: Pre (22.2; CI 18.5 to 23.5 ml/kg/min); Post (22.8; CI 21.6 to 30 ml/kg/min) CG: Pre (19.9; CI 17.2 to 22.9 ml/kg/min); Post (20.1; CI 17.0 to 24.0 ml/kg/min)
Onofre 2017 [6]	ET *n* = 06, 06 W; 40.3 ± 10.7 CG *n* = 06, 06 W, 39.5 ± 7.2	RGYBP (ET *n* = 03; CG *n* = 05); gastric sleeve (ET *n* = 03; CG *n* = 01)	03 months; combined (aerobic + resistance); 40–60% and 85–90% HRR/60–80% 1RM; 3×/week; 60 min; 03 months	ET 98.2 ± 15.5 kg CG 98.9 ± 19.6 kg	ET − 10.8 kg (CG − 8.9 kg)	ET: Pre (19.8 ± 2.6 ml/kg/min); Post (24.7 ± 5.6 ml/kg/min) CG: Pre (20.3 ± 2.9 ml/kg/min); Post (19.3 ± 4.9 ml/kg/min)
Shah 2011 [3]	ET *n* = 21, 19 W; 47.3 ± 10.0 CG *n* = 12, 11 W, 53.9 ± 8.8	RGYBP (ET *n* = 06; CG *n* = 04); GB (ET *n* = 15; CG *n* = 08)	17 (3–102) months; aerobic; 60 to 70% VO_2max, 5×/week; NR 03 months	ET 110.3 ± 16.6 kg CG 101.4 ± 8.7 kg	ET − 4.2 kg (CG − 4.7 kg)	ET: Pre (17.4 ± 3.3 ml/kg/min); Post (19.2 ± 4.2 ml/kg/min) CG: Pre (17.6 ± 1.4 ml/kg/min); Post (17.1 ± 1.7 ml/kg/min)
Stegen 2011 [9]	ET *n* = 08, 07 W; 39.9 ± 9.9 [CG *n* = 07, 04 W, 43.1 ± 5.6]	RGYBP	01 months; Combined (aerobic + resistance); 60 to 75% HRR and 1RM; 3×/week; 75 min; 03 months	ET 130.8 ± 17.8 kg CG 126.5 ± 24.7 kg	ET − 22.7 kg (CG − 26.6 kg)	ET: Pre (17.6 ± 3.2 ml/kg/min); Post (22.1 ± 5.1 ml/kg/min) CG: Pre (17.4 ± 4.9 ml/kg/min); Post (21.8 ± 6.3 ml/kg/min)

Data presented: mean ± SD or median (ranger). *CI*, confidence interval of 95%; *ET*, exercise training; *CG*, control group; *RGYBP*, Roux-en-Y gastric bypass; *GB*, gastric banding; *maxHR*, maximum heart rate; *1RM*, 1 maximum repetition; *HRR*, heart rate reserve; *VO_2max*, maximal oxygen consumption; *NR*, not reported

First author, Year	Sample size ET	Sample size CG	SMD	[LL; UL]	P-value	Relative weight
Coen, 2015	50	51	0.357	[-0.036; 0.750]	0.075	48.35
Huck, 2015	7	8	0.500	[-0.530; 1.530]	0.341	7.04
Nunez Lopez, 2017	11	11	0.374	[-0.469; 1.217]	0.385	10.52
Marchesi, 2015	7	10	0.235	[-0.734; 1.204]	0.635	7.96
Onofre, 2017	6	6	1.291	[0.0470; 2.535]	0.042	4.83
Shah, 2011	21	12	0.715	[-0.015; 1.445]	0.055	14.03
Stegen, 2011	8	7	0.020	[-0.995; 1.034]	0.970	7.26
Summarized effect	**110**	**105**	**0.430**	**[0.157; 0.704]**	**0.002**	**100**

Tau^2 = 0.00; Q = 3.38; df = 6.00; p = 0.76; I^2 = 0%
Test for overall effect z: 3.08 (p = 0.002)

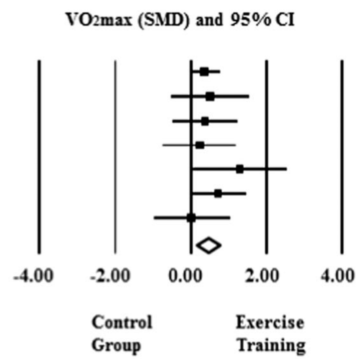

Fig. 1 Forest plot for differences between exercise training (ET) and control group (CG) (Reviewer #2/Comment #2) on reduction or increase VO_2max effect size. SMD, standardized mean difference; LL, lower limit of 95% CI; UL, upper limit of 95% CI; CI, confidence interval

absolute VO_2max values); however, reducing body weight alone was not enough to increase the VO_2max post-BS in two studies [3, 6] and the comparison with a CG in the present meta-analysis ensure the exclusive training intervention influence on the increase in VO_2max post-BS.

Although the reduction in body weight following BS could partially contribute to relative VO_2max increase, CRF could be negatively affected by the cardiorespiratory and metabolic function changes post-BS such as elevated cardiac stress, loss of muscle mass and strength, and the deterioration of oxidative muscle metabolism [4, 8, 10, 12]. Given these changes and the role of skeletal muscle metabolism in exercise capacity, the restoration or prevention of muscle mass [7, 10] must be considered in exercise training protocol design [5] for patients undergoing BS. This demonstrates the importance of including resistance/aerobic or combined training in exercise training protocols for patients undergoing BS in order to improve muscle mass and CRF. Interestingly, our exploratory analysis also demonstrated no significant differences between increases in RCTs using absolute [4, 8] or relative VO_2max [3, 5–7, 10] (SMD 0.60 (95% CI 0.12; 1, 07) and SMD 0.34 (95% CI: 0.01; 0.68), respectively), in RCTs using programs with training durations of ≤ 3 months [3, 6, 7, 10] and > 3 months [4, 5, 8] (SMD 0.36 (CI 0.004; 0.71) and SMD 0.53 (CI: 0. 10; 0.95), respectively). The results from these analyses indicate that exercise training can significantly improve VO_2max, in both shorter and longer interventions. The results were similar regardless of the use of relative or absolute VO_2max.

Compliance with Ethical Standards

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

Ethical Approval All procedures were in accordance with good clinical practice and within the Declaration of Helsinki.

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