Research Square

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Effects of a 12-week supervised exercise program post bariatric surgery on aerobic power and endurance

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Abstract

Introduction: The impact of exercise training on $\dot{V}O_2$peak and the 6-minute walking distance (6MWD) is not well defined in participants with severe obesity undergoing bariatric surgery. The objective of the study is to evaluate the effects of a 12-week combined aerobic and resistance exercise program initiated after bariatric surgery on $\dot{V}O_2$peak and 6MWD, and to assess physiological responses during the 6MWT.

Methods: Following bariatric surgery, participants were randomized (2:1) to usual care (control group [CG], n=7) or supervised exercise training (exercise group [ExG], n=13). The ExG completed a 12-week program between 3 and 6 months post-surgery. The 6MWT, combined with portable breath-by-breath gas exchange and ECG monitoring, was performed pre-surgery, at 3, 6, and 12 months post-surgery.

Results: Both groups showed reductions in body mass at 12 months (−40.4±8.1% in ExG; −38.0±7.7% in CG; p<0.001). The 6MWD increased significantly over time in both groups, with no between-group differences (p=0.55). At 25% of the 6MWT duration, participants in both groups reached >85% of peak $\dot{V}O_2$ values. No differences were observed in heart rate, respiratory exchange ratio, or oxygen pulse between groups.

Conclusion: A supervised 12-week exercise program did not provide additional improvements in $\dot{V}O_2$peak or functional capacity beyond bariatric surgery alone in participants with severe obesity.

Key Points

• Bariatric surgery improves walking distance.

• At 25% of the 6MWT, both groups achieved > 85% of their physiological peak values.

• No additive effect of a 12-week supervised exercise program on walking distance.

Introduction

Obesity is a global public health issue. The condition is tradionnaly defined by a body mass index (BMI) ≥ 30 kg/m² and is further categorized into three classes based on severity: Class 1 includes individuals with a BMI between 30 and 34.9 kg/m², Class 2 ranges from 35 to 39.9 kg/m², and Class 3, also referred to as severe obesity, applies to those with a BMI ≥ 40 kg/m².[1–3] Compared with healthy persons, individuals with obesity exhibit a higher oxygen ($\dot{V}O_2$) uptake at an equivalent absolute workload, largely due to their greater body mass and the associated increase in metabolic demands. These factors contribute to a lower peak aerobic power, measured as decreased peak oxygen uptake ($\dot{V}O_{2peak}$), that is due to central (cardiac) or peripheral (peripheral vascular, skeletal muscle) limitations.

Bariatric surgery is a well-established treatment for severe obesity.[4] Following substantial weight loss, it has been shown to improve $\dot{V}O_{2,}$ muscular strength and endurance, flexibility, physical function and body

composition.[4] In a prospective cohort of 31 individuals with severe obesity, one year post–bariatric surgery weight loss was associated with lower $\dot{V}O_{2peak}$, heart rate (HR), and systolic blood pressure during a symptom-limited cardiopulmonary exercise test. According to one prospective study in 15 individuals with obesity, there was a significant 31% increment in aerobic endurance, measured as the distance walked in 6-minutes (6MWD), compared to pre-surgery assessments.[5] Dyspnea scores after the 6-minute walking test (6MWT) were improved significantly postoperatively.[5]

In addition to the impact of surgery-induced weight loss, post-operative aerobic and/or resistance training may lead to additional improvements in the physical function and $\dot{V}O_{2peak}$ in individuals with severe obesity.[6, 7] In a non-randomized interventional study of 15 patients undergoing gastric bypass surgery, participants were allocated to either a 4-month endurance and strength training program or standard care. The exercise group demonstrated a greater improvement in 6MWT distance (52 ± 30 m, $p < 0.002$) compared with standard care (30 ± 68 m, $p = 0.33$); however, no significant between-group differences were observed ($p = 0.43$).[7] Studies using an exercise training program in individuals with severe obesity who underwent a bariatric surgery remain scarce, despite the added potential benefit of exercise training might have regarding physical function or cardiorespiratory function (CRF) improvement. To our knowledge, no randomized controlled trial using the 6MWT with $\dot{V}O_2$ to assess CRF in individuals with severe obesity post bariatric surgery following a supervised exercise program have been reported.

The main objective of this study was to assess the effect of a 12-week exercise program post bariatric surgery on the walking distance as well as CRF during the 6MWT, in individuals with severe obesity. The secondary objective was to evaluate the physiological demand of the 6MWT through respiratory exchange ratio (RER), oxygen pulse (O_2pulse) and HR responses.

Materials and Methods

Study Design and Participants

This study is a sub-analysis derived from a prospective randomized trial conducted at “xxx”. Sixty participants with severe obesity, aged between 18 and 65 years old, who planned to undergo biliopancreatic diversion with duodenal switch (n = 30) or sleeve gastrectomy (n = 30) were recruited between 2012 and 2015 through the bariatric surgery clinic of the “xxx”. The study used a stratified randomization according to the type of bariatric surgery, and participants were allocated to an exercise program (ExG) or a control group (CG) (2:1 ratio). All participants were evaluated prior surgery (baseline) and at 3, 6, and 12-months post-surgery (Fig. 1). Exclusion criteria included pregnancy, preoperative body weight ≥ 200 kg, previous vagotomy, major cognitive deficit limiting adherence to visits, pacemaker, total hip prosthesis, claustrophobic condition, or Orlistat utilization in the last 3 months prior surgery. The study protocol was approved by the ethics committee of “xxx”. Informed consent was obtained from all

individual participants included in the study. The trial is registered with ClinicalTrials.gov, number NCT“xxx”.

Study Interventions

The participants randomized to the ExG underwent a supervised exercise training program between the 3rd and the 6th months after the bariatric surgery procedure (Fig. 1). The exercise-training program consisted of a 60-min session divided into a 35-min period of aerobic training and a 25-min period of resistance exercises, thrice weekly. The aerobic training (treadmill or ergocycle) was defined as a moderate-to-vigorous intensity training, according to the HR reserve (60–75%) derived from the CRF test ($\dot{V}O_{2peak}$) previously measured.[8] Resistance exercises consisted of 3 series of 10 to 12 repetitions targeting large muscle masses (i.e. leg extension, squats and seated low row at the pulley), as up to the point of muscular fatigue. A certified clinical exercise kinesiologist accredited by the American College of Sports Medicine (ACSM) supervised each exercise session. Participants randomized to the CG received usual post-surgery care, consisting in general advice regarding physical activity during a 1-hour meeting with a kinesiologist at 3 and 6 months after bariatric surgery.

Medical History and Anthropometric Measurements

All participants were evaluated preoperatively and at 3, 6 and 12-month following bariatric surgery. Demographic characteristics, medical health conditions and tobacco status were collected. Total body weight, body fat and fat-free mass (FFM) were assessed using a bioelectrical impedance balance (Tanita TBF-350, Tokyo, Japan). Height was measured with a stadiometer and BMI was calculated using body weight and height and expressed in kilograms per squared meters (kg/m^2). Waist circumference (WC) was measured using a measuring tape (Seca 201, Hamburg, Germany) according to standardized procedures.[9]

6-Minute Walking Test

The 6MWT was administered according to the American Thoracic Society.[10] Preceding by standardized instructions, participants had to walk the longest distance possible for a period of 6 minutes, without running, in a 30-meter flat corridor. All participants wore a portable gas exchange analyzer (Oxycon mobile, CareFusion, San Diego CA), which measured the level of oxygen consumed from which the $\dot{V}O_{2peak}$, O_2pulse and Respiratory Exchange Ratio (RER) were obtained.[11] Participants also carried a 12-lead electrocardiogram, which does not exceed 2 kilograms of weigh during the 6MWT, from which HR was collected. All tests were administered by a certified clinical exercise kinesiologist from the ACSM and supervised by a physician.

Statistical analysis

Characteristics at baseline prior surgery were expressed as means ± standard deviations (SD) for continuous outcomes and proportions for dichotomous outcomes. Characteristics between groups at baseline were compared using chi-square tests or independent t-tests, for dichotomous and continuous variables, respectively. To compare the total walking distance during the 6MWT between groups, a linear mixed model was adjusted using the groups and time (four visits) as fixed factors and the participants as a random factor. An interaction term between the groups and time was added in the statistical model. The dependence among residuals of repeated measurements from the same experimental unit were estimated with an autoregressive covariance structure. To analyse $\dot{V}O_{2peak}$, O_2pulse, HR and RER data, a second repeated measure was added to the statistical model with a direct product compound symmetric covariance structure to measure the dependence among residuals. The normality assumption was verified with the Shapiro-Wilk tests using residuals from the statistical model and transformed by the Cholesky's metric. In case the normality assumption was violated, data were log-transformed to fulfill the normality and variance assumptions. The Brown and Forsythe's variation of Levene's test was used to verify the homogeneity of variances. A *posteriori* multiple comparisons were performed using the Tukey's test. Results were considered statistically significant with a p value < 0.05. Analyses were performed using using SPSS v.25 (Chicago, IL, USA, 2013) for comparison of baseline characteristics and SAS version 9.4 (SAS Institute Inc, Cary, NC) for repeated measures analyses.

Results

Participants Characteristics and Anthropometric Measurements

Participant's flowchart is presented in Fig. 1 in the supplemental materials. From the 60 participants initially randomized, a total of 20 participants were included in this analyses. Reasons for the discontinuation of participants were participants personal decision (n = 5). From the remaining missing data (n = 35), 43% were due to missing values during follow up periods and 57% were outlier values due to equipment or recording issues. When comparing the characteristics and anthropometric values of the excluded participants (n = 35) with the included participants (n = 20), there was no significant difference between them at baseline and 3-months' time post bariatric surgery. On average, 76% of the exercise sessions were completed. Baseline characteristics of included participants (n = 20) are presented in Table 1. Through the whole follow-up period (from baseline to 12 months), every anthropometric measurement improved significantly (p < 0.05), with no statistical difference observed between the ExG and CG (Table 1). Mean weight loss at 6 months was 30.6 ± 5.1% in the ExG and 28.6 ± 3.9% in the CG (p = 0.36). Exercise training did not confer an additional effect on changes in body composition, fat distribution, or FFM.

Table 1
Descriptive characteristics of patients.

	All patients (n = 20)	Exercise Group (n = 13)	Control Group (n = 7)	P value
Anthropometric measures				
Age (years)	42 ± 12	45 ± 12	37 ± 13	0.18
Body mass (kg)	125.9 ± 19.4	119.9 ± 10.3	137.0 ± 27.6	0.16
Body mass index (kg/m^2)	46.1 ± 4.6	46.2 ± 4.3	46.0 ± 5.5	0.88
Waist circumference (cm)	134.2 ± 4.6	130.8 ± 9.3	140.5 ± 9.3	0.04
Fat percentage (%)	50.0 ± 6.0	51.8 ± 2.5	47 ± 9.2	0.22
Fat free mass (kg)	62.8 ± 12.3	57.7 ± 3.2	72.3 ± 17.3	0.07
Medical History				
Type 2 Diabetes - n (%)	4 (20)	2(15)	2(29)	0.48
Hypertension - n (%)	7 (35)	5(38)	2(29)	0.66
Dyslipidemia - n (%)	7 (35)	5(38)	2(29)	0.66
Smoker - n (%)	2 (10)	1(8)	1(14)	0.64
6 Minutes Walking Test				
Distance (m)	475.5 ± 69.4	489.2 ± 53.5	450.0 ± 91.6	0.24
$\dot{V}O_{2peak}$ (mL/min)	1935.4 ± 403.1	1927.6 ± 408.1	1949.9 ± 425.7	0.91
$\dot{V}O_{2peak}$ (mL/kg/min)	15.5 ± 3.3	16.1 ± 3.4	14.4 ± 3.1	0.27
$\dot{V}O_{2peak}$ – (mL/kg FFM/min)	62.8 ± 12.8	61.3 ± 9.7	65.4 ± 16.8	0.49
Heart rate (bpm)	142 ± 23	145 ± 22	137 ± 24	0.27
RER	1.03 ± 0.10	1.02 ± 0.08	1.06 ± 0.12	0.02
Oxygen pulse (mL/beat)	14.1 ± 2.3	13.8 ± 2.0	14.7 ± 2.9	0.10

Mean ± standard deviation or number (%). $\dot{V}O_{2peak}$: peak oxygen consumption, RER: respiratory exchange ratio.

6-Minute Walking Test

The progression of the walking distance for each visit in each group is shown in Fig. 1. A significant increase in the walking distance was observed from baseline (before bariatric surgery) to 3 months (7.9

± 7.5% ExG and 15.3 ± 20.1% CG), to 6 months (17.0 ± 9.1% ExG and 20.7 ± 31.1% CG) and to 12 months (23.5 ± 8.4% ExG and 28.2 ± 34.3% CG) without difference between groups (p = 0.55). Despite a significant reduction for absolute $\dot{V}O_{2peak}$ and an increase for the $\dot{V}O_{2peak}$ relative to weight across the study visits, there was no difference between groups for absolute $\dot{V}O_{2peak}$, and $\dot{V}O_{2peak}$ relative to FFM in contrast to $\dot{V}O_{2peak}$ relative to weight, where a difference between CG and ExG at each study visit were observed (p = 0.04) (Fig. 2).

At each visit (baseline, 3, 6 and 12-month), there was no difference between groups regarding maximal HR, O_2pulse, as well as RER (Fig. 3). The progression of parameters in both groups are reported in Table 1 of supplemental material and presented in Fig. 2. Both groups evolve similarly from baseline to 12 months from 0-100% of the 6MWT. During the 6MWT, there were no statistically significant difference in the area under the curve (AUC) for all values (RER, O_2pulse, and HR) (Table 2, supplemental material). At 25% of the 6MWT, both groups achieved > 85% of their peak values for $\dot{V}O_{2peak}$, $\dot{V}O_{2peak}$ relative to body mass, $\dot{V}O_{2peak}$ relative to FFM, RER, O_2pulse and HR (Fig. 2, supplemental material).

Discussion

To the best of our knowledge, this is the first study to measure $\dot{V}O_2$ during the 6MWT examining the effects of a 12-week exercise program on the $\dot{V}O_{2peak}$ as well as the walking distance in individuals with severe obesity following bariatric surgery. The major findings of this study are: 1) bariatric surgery improves walking distance, 2) at 25% of the 6MWT, both groups achieved > 85% of their physiological values peak values and, 3) there was no additive effect of a 12-week supervised exercise program on CRF, walking distance, body composition and the 6MWT physiological demand.

Maximal Walking Distance

The 6MWT is a useful test for the evaluation of functional capacity as it is prognostic of morbidity and mortality in patients with chronic obstructive pulmonary disease[12] and heart failure.[13] There are significant improvements in the walking distance in the 6MWT following an exercise intervention in diverse pathologies.[13–15] Regarding the walking distance post bariatric surgery, it was observed in a prospective study 1 year following bariatric surgery in 15 patients, that weight loss significantly increases walking distance by 151 m.[5] A non-randomized control trial in 15 patients with severe obesity undergoing 12 weeks of aerobic and resistance training post bariatric surgery, reported a significant improvement in walking distance in the exercise group without any differences between groups.[7] The same results were observed in a randomized study conducted in 40 participants with obesity undergoing an exercise training program post bariatric surgery.[15] Similarly, we observed a significant increase in 6MWD by 115 m 12 months after bariatric surgery.

Physiological Parameters During The 6 Minutes Walking Test

There was no significant difference between the ExG and CG regarding peak physiological variables such as O_2pulse, RER, HR, absolute $\dot{V}O_{2peak}$ or indexed to FFM. It is known that individuals with severe obesity have impaired CRF.[8, 16, 17] Studies reported increases in $\dot{V}O_{2peak}$ relative to body weight following bariatric surgery.[18–28] In contrast, this finding is not the same regarding absolute $\dot{V}O_{2peak}$, which is either unchanged[18, 25, 26, 28] or decreased.[19, 21–24] This is in accordance with our results observed at 3-months post bariatric surgery. The improvements in relative $\dot{V}O_{2peak}$, in contrast to the decrement in absolute $\dot{V}O_{2peak}$ post-surgery, are suggested to be mainly attributed to weight loss rather than important improvement in the cardiopulmonary fitness.[29] There are conflictual results pertaining to the effects of exercise training post bariatric surgery. Contrary to our hypothesis, there was no additive effect of a 12-week exercise program post bariatric surgery on the $\dot{V}O_{2peak}$ relative to body mass and relative to FFM. This is in accordance with some studies[8] and contrary to others.[7, 30–33] This is likely attributable to the lack of standardized exercise protocols and the variability in follow-up durations.

Respiratory Exchange Ratio

Higher RER is an indication of a physical activity of higher intensity, and proximity to volitional exhaustion.[34] We documented an increase in RER values 1 year post bariatric surgery and a decrease at 3-months (closer to the postoperative period). This improvement long-term as opposed to the initial postoperative period is consistent with the literature documenting unchanged or decreased RER in immediate follow-up periods and increased RER in later follow-up periods post bariatric surgery.[18, 19, 21, 24, 26, 28] Weight loss in individuals with obesity results in lower O_2 uptake, and HR for the same amount of external work, therefore a lower energy consumption.[26] Individuals post bariatric surgery achieved higher RER,[7, 35, 36] suggesting an increased exercise intensity.[19, 26, 37] In a prospective 1-year follow up study in 31 individuals with severe obesity, 83% of participants attained their maximal HR with RER value < 0.9 during a cardiopulmonary exercise test (CPET). After bariatric surgery, 90% of patients reached maximal HR at a RER > 1.0,[26] suggesting that exercise training may have facilitated higher exercise intensity tolerance, allowing participants to achieve greater RER values.

Heart Rate

An increase in the sympathetic nervous system activity in individuals with severe obesity has been observed.[38] No significant difference in HRmax after 3 months of exercise training post-surgery between the control and the intervention groups was found in 12 individuals with obesity after gastric bypass.[38] In addition, a reduction in HRmax was observed in both groups as in our study. The reduction in HRmax may be attributed to a reduction in the blood volume accompanied by loss of body weight following bariatric surgery.[35, 39, 40] There is also a modulation in the autonomous nervous system along with the weight loss following bariatric surgery.[35, 39, 40] Also, the lower HRmax can be explained by a better parasympathetic cardiac modulation.

Physiological demand of the 6MWT: test evolution

There was no effect of exercise training on the physiological demand of the 6MWT. Our results show similar physiological demands during the 6MWT in the CG and the ExG from resting values up to 100% of the test and this at each visit. Participants attain > 85% of the $\dot{V}O_{2peak}$ values at 25% of the test. Consequently, participants were at > 85% of their peak values for 75% of the duration of test. Our group reported the same physiological demand during the 6MWT in patients with severe aortic stenosis[11]. Our findings demonstrate that the 6MWT involves a high physiological cardiac and pulmonary demand in individuals with severe obesity.

Strength and Limitations

The strength of this study is the study design using direct measurement of gas exchange during the 6MWT, which allowed us to analyze various physiological parameters such as the CRF ($\dot{V}O_{2peak}$), RER, HR, and O_2pulse. Despite the use of direct measurement during the 6MWT, we acknowledge that a maximal exercise test is the gold standard to assess the CRF using CPET. The main limitation of this study is the sample size, which limits the generalization of the findings. Some patients were excluded from the final analysis because of missing data at 3 and 6-month follow-up periods (43%), others due to outliers values caused by equipment and recording issues (57%) which further decreases the sample size. Another limitation underlies in the number of sessions completed by the exercise group. Indeed, only 28% of the participants performed 85% of the exercise training sessions. Nervertheless, our findings illustrate that the 6MWT imposes significant physiological demands on the cardiac and pulmonary systems in individuals with severe obesity.

Conclusion

Bariatric surgery was associated with improved walking distance. Both groups achieved > 85% of their peak physiological values early in the 6MWT, and a 12-week supervised exercise program did not confer additional improvements in CRF, walking distance, body composition, or test demands.

Declarations

Author Contribution

AA, MT, AL : wrote the main manuscript textAA: conduct the trial and review the manuscriptMP and MH: review the manuscriptSO and SA: support for the statistical analysis and review the manuscriptPP: principal investigator of the trial, conduct the trial, review the manuscript.

Conflicts of Interest Disclosure Statement

The authors declare that they have no conflict of interest.

Statement of Human Rights

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional.

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Figures

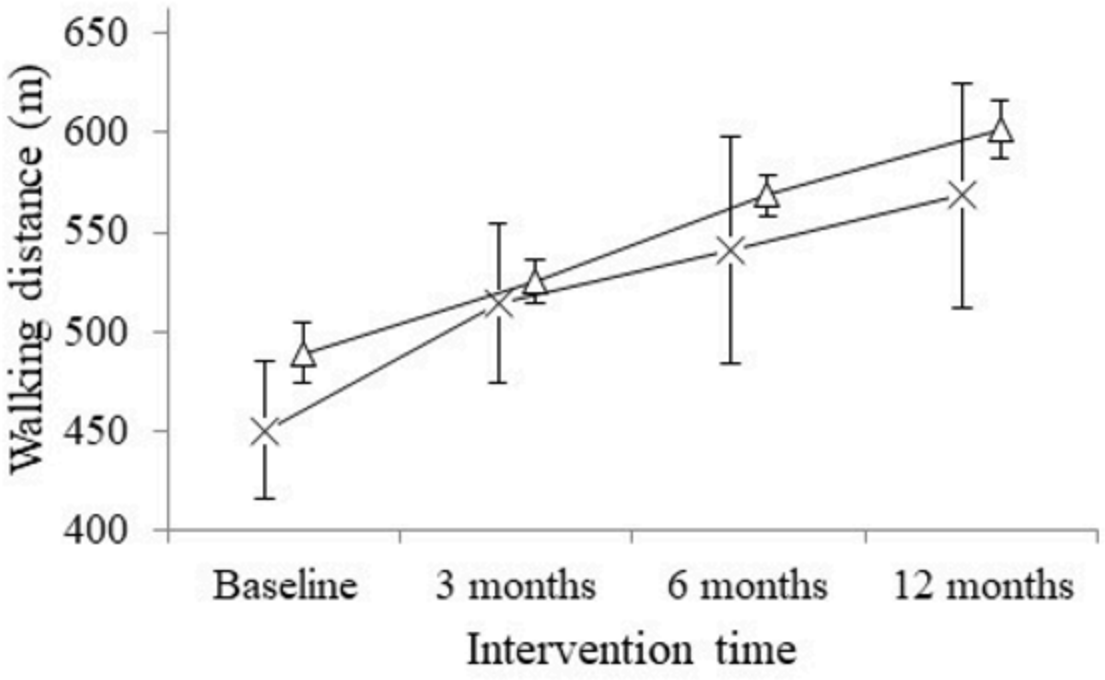

Figure 1

Walking distance progress in 6-minute walk test

Mean ± standard error

X: Control group; Δ: Exercise group

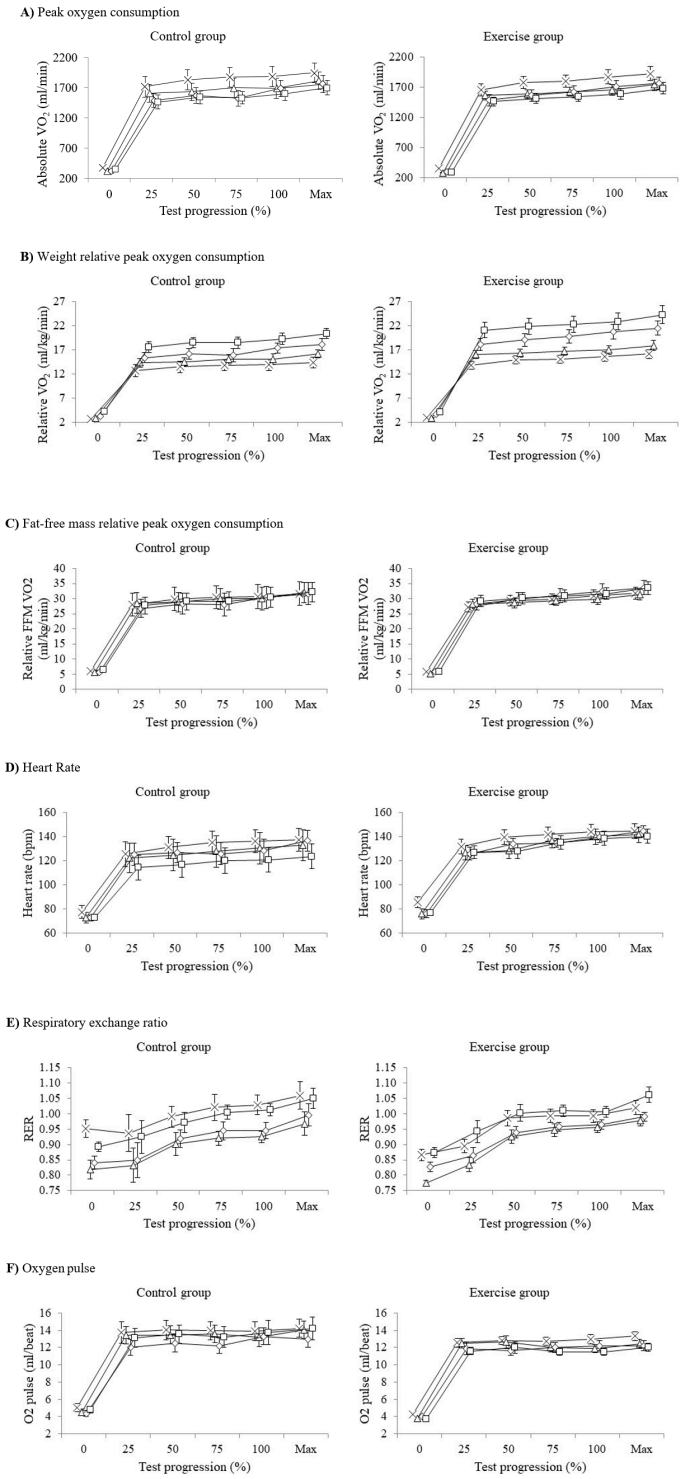

Figure 2

Progression of exercise parameters in exercise and control group at each time intervention

Mean ± standard error

X: Baseline; Δ: 3 months; ◊: 6 months; □: 12 months

VO_{2peak}: peak oxygen consumption, FFM: Fat-free mass, bpm: beats per minute, RER: Respiratory exchange ratio, O_2 pulse: oxygen pulse

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supp.docx