Electronic Journal of General Medicine
2025, 22(1), em628
e-ISSN: 2516-3507
https://www.ejgm.co.uk/

MODESTUM

Original Article

OPEN ACCESS

Impacts of bariatric surgery on exercise capacity, body composition, pulmonary functions, muscle strength, and physical activity in individuals with obesity: A cross section study

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Citation: Alahmed SAS, Shanb AA, Alsubaiei ME, Youssef EF, AL-Ali AJ. Impacts of bariatric surgery on exercise capacity, body composition, pulmonary functions, muscle strength, and physical activity in individuals with obesity: A cross section study. Electron J Gen Med. 2025;22(1):em628. https://doi.org/10.29333/ejgm/15903

ARTICLE INFO

Received: 27 May 2024

Accepted: 03 Jan. 2025

ABSTRACT

Background: Among multiple therapeutic options of obesity, bariatric surgery (BS) sometimes is the most superior, and effective practical method of weight loss for obese individuals.

Objective: This study aimed to determine impacts of BS on exercise capacity, body composition, pulmonary functions, isometric muscle power, hand grip strength, and physical activity (PA) in patients underwent BS.

Materials and methods: Twenty-four patients with BS (body mass index [BMI] ≥ 35) participated in a cross-section study. Exercise capacity, body composition, pulmonary functions, isometric muscle power, strength of hand grip, and PA were measured pre- and post-surgery by three months by using VO_2 max, bioelectrical impedance, spirometer, handheld dynamometer, jammar hand grip, and international physical activity questionnaire, respectively. The Wilkson test was used to detect significant differences within a group for non-normal variables whereas the paired t-test was used for normal variables.

Results: Show significant reductions in body weight, BMI, fat mass (FM), fat-free mass (FFM), hand grip strength and muscle mass (MM), in addition significant improvements in exercise capacity, maximal forced vital capacity, and PA (p-value < 0.05); whereas non-significant differences were obtained in isometric muscle power and pulmonary functions (p-value > 0.05).

Conclusion: Lifestyle modifications are the cornerstone for success of all outcome measures of weight loss after BS. Although achieved significant improvements in body composition including FM, percent of fat, FFM and MM; maximal exercise capacity, hand grip strength, and PA after BS, those patients still need for early interventions with individualised rehabilitative training programs to improve their capabilities and general health.

Keywords: obesity, bariatric surgery, exercise capacity, weight loss, pulmonary functions, physical activities

INTRODUCTION

Obesity is excess accumulation of fat in certain areas of the body [1]. It is a public health problem affecting the population in many countries, its prevalence rate increases particularly in the absence of preventive measures [2], more than 400 million people will suffer from obesity in the coming years [3]. The percent of overweight and obesity in the Saudi Arabian is 32.8% and 23%, respectively [4]. Morbid obesity is a serious health condition that is diagnosed by being have a body mass index (BMI) greater than 40 kg/m^2, and a BMI of greater than 35 kg/m^2 with at least one co-morbidity. Obesity can cause over 150 diseases, affecting both sex and people of all ages [5]. It financially burdens the healthcare system from different aspects [6] because it is a major risk factor for cardiovascular disease, type-II diabetes, dyslipidemia, sleep apnea [2], fatty liver [1], depression, orthopedic disability, infertility [7], increases the risk of cesarean-section [1], low self-esteem, impairment of the body image and low quality of life [8].

Obesity is managed through several approaches by multidisciplinary clinical team members, e.g., re-education about healthy habits, prescribtion of low-calorie diets, increases of physical activities, medications, and psychological support ending with bariatric or metabolic surgery [9].The Saudi ministry of health committed the medical insurance companies to cover the financial costs of treating morbid obesity[5], in parallel with the vision of 2030, multiple strategies were established to fight obesity [10]. Changing one's diet is an essential component of lifestyle modifications [11]. Low-carbohydrate diets are effective because they reduce both the consumption of carbohydrates and secretion of

insulin [11], also the intermittent fasting decreases all cardiovascular risk factors through better glucose control and increases insulin sensitivity [11]. Exercise plays a crucial role in preventing and managing obesity through increases energy expenditure and level of physical activity (PA) including occupational activity, working around the home, personal care, and leisure-time activities [12].

Anti-obesity medications are indicated for individuals with a BMI ≥ 30 kg/m^2 or a BMI ≥ 27 kg/m^2 in presence of one or more comorbidities [13]. Bariatric surgery (BS) aimed to reduce an individual's body weight and to treat type-II diabetes [2], thus BS is indicated for all patients with a BMI ≥ 35 kg/m^2 and in presence of at least one comorbidity, while metabolic surgery is used mainly to treat patients with diabetes and metabolic dysfunction and whose previous treatment regimens have not had the desired outcomes [14].

VO_2 max is used for evaluating cardiopulmonary functions and exercise capacity [15]. It is estimated by using a maximum or sub-maximum exercise test [16]. Its values are determined for athletes to predict their performance while for diagnostic use in those individuals with different pathological conditions [15]. VO_2 max is affected by cigarette smoking, percent of body fat, muscle mass (MM) [17], age, gender, and method of assessment [18]. Low VO_2 max is related to all causes of morbidity and mortality [15].

Detection of body composition is an accurate way to measure fat mass (FM), fat-free mass (FFM), fat percent and the skeletal MM of the upper and lower limbs [19]. Lean tissue mass is the sum of the lean MM, free fat mass and essential fat. Although the first six months after BS are associated with rapid weight loss [20], 20-30% of patients could not achieve the target weight-loss [21]. BS is associated with loss of FM, MM, and FFM [22], which plays a vital role in physiological processes, e.g., immune response, regulation of glucose levels, protein synthesis and basal metabolic rate [21]. Coordination and integration of electrical, and chemical events and structural components of muscular tissue are essential for muscular power [23] and achieving any proper functional capacity [24]. Muscle power is affected by muscle size, exercise capacity, intermuscular adipose tissue, neuromuscular activation [25], morbid obesity, rapid weight loss after diet and physical inactivity [26]. BS usually results in protein mal-absorption which impacts muscular mass and strength particular in the first year [27]. Also, patients of BS are at risk for developing sarcopenic obesity, low MM and physical function [27], muscle atrophy [22], significant reductions in VO_2 max and muscle power of both upper and lower limbs [28].

Central type of obesity negatively impacts the pulmonary functions more than peripheral obesity [29]. Morbid obesity is a common risk factor for obstructive sleep apnoea (OSA) [30]. Many obese patients are diagnosed with respiratory diseases and OSA associated with autonomic fluctuation and sleep fragmentation [30].

After BS significant reductions were determined in body weight, BMI, waist circumference, and waist/hip ratio with improvements in pulmonary functions, particular the FEV_1, and forced vital capacity (FVC) [27, 31, 32], BS has positive impacts on patients with OSA by eliminating apnoea-hypopnea events, reducing weight, sleep fragmentation, and increasing oxygen saturation [33]. PA means any type of body movements, including activity of daily living, instrumental daily activity and exercise [34]. PA protects against coronary heart disease, type-II diabetes and all causes of death [35], also PA promotes weight loss, increases energy expenditure, maintains MM, improves cardiovascular health, decreases anxiety and depression in addition improvements of metabolic parameters, including blood glucose, pressure and lipids [36]. Moderate-intensity PA prevents weight regain, improves quality of life [37], and the level of activity of daily living [35]. BS is being successful if a patient loses 50% or more of his or her extra-weight and achieves a BMI < 35 kg/m^2, there is no doubt that PA plays a core role in preventing weight regain after surgery [38]. Despite all associated benefits of PA after BS, still there are barriers to compliance to PA regimens [36], e.g., time conflicts, financial issues and difficulty adapting to programs, however, specific strategies can improve adherence to PA programs, e.g., phone applications and smartwatches [39].

Previous results of BS on VO_2 max show controversial findings [6, 28, 40-42]. However, its mean values show increases in [6, 40, 41], decreases in [28] or unchang in [20], also age, gender and BMI of patients'sample in [41], ranges from 20 to 45 years with BMI ≥ 30 kg/m^2, or included only female patients in [6, 28, 42]. The time of patients' evaluation may widely differ after surgery by 24 months [42] or one year [40] or post six months [20]. In addition increases in the prevalence rate of obesity all over the world, particularly in Saudi Arabia, 33.7% of women and 29.5% of men are obese, respectively [4]. The traditational conservative therapeutic approaches are not effective in weight reductions for many obese individuals,thus BS becomes the only option to overcome extra-weight and get rid of associated comorbidities and complications, this increases demands on BS with its advantages and disadvantages on different body systems; so impacts of BS on VO_2 max, body composition, PA and muscle strength still requires further investigations with in addition, this is the first conducted study in Saudi Arabia. Therefore, the current study aimed to investigate short term impacts of BS on exercise capacity, body composition, pulmonary functions, isometric muscle power, strength of the hand grip, and PA in individuals who underwent baratric surgery.

MATERIALS AND METHODS

Study Design

Cross-section study.

Sample Size

It was calculated using an online cite (https://sample-size.net/sample-size-study-paired-t-test/), based on values of means,standard deviations for VO_2 max in the previous study [41]. The significant value is 0.05, with a power of 95%. The total sample size including perecent of drop out was 24 patients of BS.

Ethical Approval

This study was conducted in accordance with international criteria for scientific research, the ethical guidance is based on the Helsinki Declaration. All procedures were approved by the Institutional Review Board at Imam Abdualrahman Bin Faisal University (IRB-PGS- 2022-03-364), Saudi Arabia. All patients signed a consent form prior to their participations, and they were informed that the collected data will be submitted for publication.

Sample of Patients

One hundred patients who underwent BS, were referred by a consultant of surgery to participate in this study.

Inclusion Criteria

All patients followed standards of indications for BS according to the Saudi Society of Bariatric and Metabolic Surgery [2], Male and female obese patients underwent BS [3], who have a BMI ≥ 40 kg/m^2 regardless of their accompanied comorbidities or BMI of ≥ 35 kg/m^2 in presence of one or more comorbidity, e.g., type-II diabetes, hypertension, sleep apnea, joint degenerative disorders, infertility, non-alcoholic fatty liver or steatohepatitis, and urinary incontinence [2].

Exclusion Criteria

All patients who had uncontrolled cardiopulmonary diseases, severe hypertension (systolic blood pressure greater than 200 mmHg, diastolic blood pressure greater than 120 mmHg or both) [43], musculoskeletal or neurological diseases that can prevent him or her from conducting the study were excluded [44].

Blinding

It is a single blinded study. All outcome measures were done and recorded by an independent assessor (research assistant).

Procedure of the Study

Male and female obese patients (who underwent BS) were referred by consultant of surgery to the out-patient clinic of physical therapy, at Almoosa Specialist Hospital in Al-Ahsa, Eastern Region, Saudi Arabia from february 2023 until october 2023.

Assessment Procedure

The following outcome measures were evaluated for all patients pre-surgical intervention by one week and after surgery by 3 months.

a. **Exercise capacity** was estimated by using the Bruce protocol [45], which is a non-invasive, moderately reliable method [46]. Each patient was asked to wear his or her comfortable clothes, avoid eating meals for the last 2 hours, avoid smoking and drinking caffeine on the same day of examination. Every patient was asked to walk on the treadmill for 3 minutes as warming up, the intensity gradually increases until the patient could no longer continue the test; it usually takes 8 to 21 minutes, depending on the patient's fitness [44], when the patient is unable to continue the test, it is ended with cooling down for other 3 minutes. The test was done under supervision of a qualified physical therapist (research assistant). The Bruce protocol was applied to estimate the VO_2 max by using these equations; for men: $VO_2\,max = 14.8-(1.379 \times T) + (0.451 \times T^2) - (0.012 \times T^3)$; for women: $VO_2\,max = 4.38 \times T-3.9$ [46].

b. **Body composition** was measured by bioelectrical impedance analysis, SECA 554 MBCA- Germany (https://www.seca.com/en_ae/554.html) [47]. It was applied to determine body composition including FM, FFM, fat percentage, and MM [48]. It is a valid applicable device. Every patient was asked to avoid heavy exercise for 4 hours before the test, and did not apply any creams to his or her hands or feet, after that he or she was asked to stand on the plate of the device, four fingers of each hand were placed in contact with the electrode, and the fingers were separated by a finger spacer, the arms were extended but not under tension. After entering personal data of patient into the system, the measurements were recorded on the system in 24 seconds.

c. **Pulmonary functions** were measured by using the spirometry (Geratherm Respiratory and the system, Germany, https://www.geratherm-respiratory.com/product-groups/pft/). It provides a valid and reliable measure for dynamic lung volumes, including FVC, which represents the amount of air that can be forcefully expelled, forced expiratory volume in one second (FEV_1), which represents the amount expelled during the first second of the FVC manoeuvre, FEV_1/FVC this ratio is indicator for obstruction in airways, forced expiratory flow rates at 25%-75% of the pulmonary volume is indicator for small airway diseases. The normal results of spirometry FEV_1/FVC ratio are greater than 0.70 and FEV_1 and FVC above 80% of the predicted values [49]. Every patient was asked to wear comfortable clothes, avoid heavy exercises and tobacco products, every patient's personal information including weight, height, were entered on the computer system of the spirometer. Each patient was asked to sit, and the nose was closed by a soft clip; put the lips around the connected mouthpiece to the spirometry and make sure there was no leakage. Each patient was asked to breathe twice normally, then to take a deep breath and blow as long and fast as possible. Perform the test 3 times, and the best results were recorded [50]. According to the American Thoracic Society the lung functions are classified into normal, if both FVC and the FEV_1/FVC ratio are in the normal range; obstructive pattern, if FEV_1/FVC ratio is < 70% of the normal predicted value and FEV_1 < 80% of the predicted; restrictive pattern, if FEV_1/FVC ratio is ≥ 70 % of the normal predicted value, and the total lung capacity < 80% of the predicted value. If total lung capacity was not available, a reduction in the FVC < 80 % of predicted is considered as a restrictive pattern, and small airway diseases, if forced expiratory flow between 25% and 75% of FVC ($FEF_{25-75\%}$) is < 65% of predicted value [51].

d. **Isometric muscle power** was measured by using the microFET®2 Hoggan Handheld Dynamometer for the selected muscles of the upper and lower extremities. It is a valid and reliable for evaluating isometric muscle power (USA Company https://hogganscientific.com/product/microfet2-muscle-tester-digital-handheld-dynamometer/) [52, 53].

   1. **Elbow flexors:** The biceps isometric muscle power was measured from a comfortable supine lying position. After fixation of the dynamometer from the supinated forearm position and by the evaluator's hand proximal to the wrist joint, every patient was asked to bend the elbow against resistance as much as possible for three trials, and the mean values were recorded [54].
   2. **Knee extensors:** The quadriceps isometric muscle power was measured from a relaxed sitting position with flex hip and knees at 90°. The dynamometer

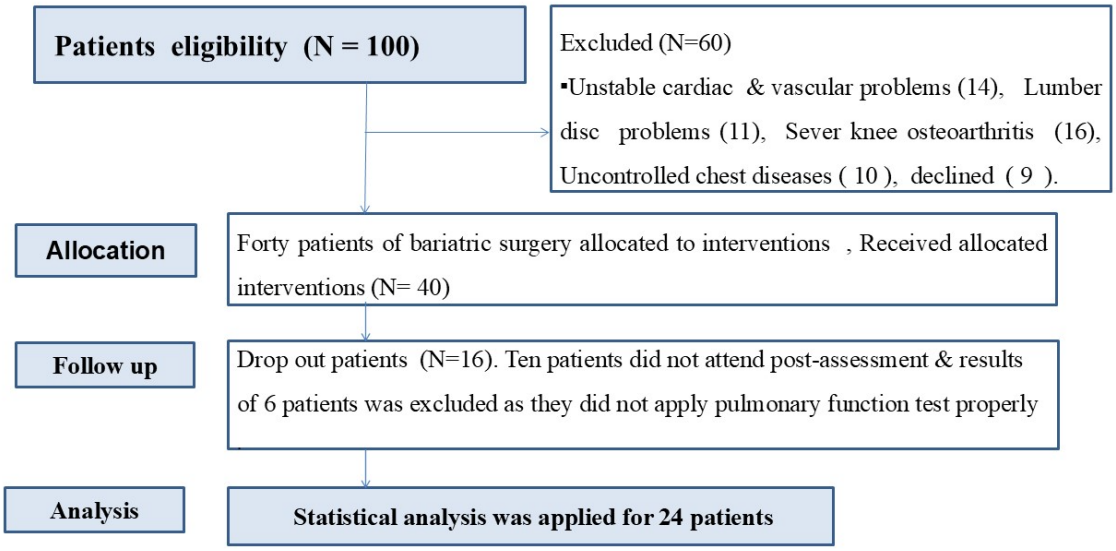

Figure 1. Flow chart of patients' recruitment (Source: Authors' own elaboration)

was fixed on the anterior by the evaluator's hand, proximal to the ankle joint. Every patient was asked to extend the knee against resistant as much as possible for three trials, the mean values were recorded [52].

e. **Strength of the hand grip** was measured by using the Jamar hydraulic hand dynamometer (Jamar Company, China), which is a valid device [55]. Each patient was asked to sit upright on an adjustable chair, with hip and knee flexed at 90°. Each patient was asked to put the arm on the table with shoulder adduct, flexed elbow at 90°, forearm 0 between supination and pronation and the wrist in a neutral position. Start with the dominant hand and the rest 30 seconds among the trails. Ask every patient to "squeeze his or her fist as hard as he or she can for 3 seconds". The test was repeated three times, and the mean values were recorded [56].

f. **Physical activity** was evaluated by using the international physical activity questionnaire–long form, Arabic version, which is a valid and reliable questionnaire [57], it evaluates adults' physical activities in the last 7 days. It includes 5 domains (job-related, transportation-related, housework, recreation; sport and leisure time, and time spent sitting) using an individual adult aged 15 to 69 years old. It consists of 27 questions [58]. The amount of PA is categorized to: High if the subject practices vigorous-intensity activity on at least 3 days, 7 or more days of any combination of walking moderate-intensity or vigorous-intensity activities; Moderate if the subject practices 3 or more days of vigorous-intensity activity and/or walking of at least 30 minutes per day, 5 or more days of moderate-intensity activity and/or walking of at least 30 minutes per day, 5 or more days of any combination of walking. Low if the subject does not meet the moderate or high PA level criteria. Every patient was asked to read and answer the questionnaire with his or her suitable responses.

Statistical Analysis

The collected data were statistically analyzed by using SPSS version 25.0. The Kolmogorov-Smirnov test was used to test normality of the data distribution. The Wilkson signed ranks test was used to compare significant differences within group for non-normal variables whereas the paired t-test was used for normal variables. Statistical significance was set at p-value < 0.05 with a confidence interval of 95%.

Table 1. Demographic data of recruited patients

Variables		Patients of BS
		Mean ± standard deviation
Age in years		32.33 ± 11.38
Gender	Female: N (percentage [%])	19 (79.2)
	Male: N (percentage [%])	5 (20.8)
Weight in kg		109.25 ± 22.02
Hight in cm		158.72 ± 7.51
BMI in kg/m^2		43.12 ± 6.39
Class of obesity: N (percentage [%])		Class-I = 2 (8.3)
		Class-II = 4 (16.7)
		Class-III = 18 (75.0)

Note. N: Number

RESULTS

Out of one hundred patients only fourty were recruited to participate in this study (**Figure 1**), 16 patients drop out because 10 patients did not attend the post-test and 6 patients did not do pulmonary function test properly. The statistical analysis was applied only for 24 patients undergone BS (16 sleeve gastrectomy and 8 by bass). Demographic data of recruited patients: Classes of obesity of included patients were two with class -I, four with class II, and eighteen with class III. Mean values of age, weight, height and BMI were 32.3 ± 11.3 in years, 109.25 ± 22.01 in kg, 158.72 ± 7.51 in cm, and 43.12 ± 6.39 kg/m^2 (**Table 1**).

The results show significant reductions in mean values of body weight, BMI, paramaters of body composition after BS by three months p-values < 0.05 (**Table 2**) while the results show significant increases in mean values of exercise capacity (VO_2 max), and PA, p-values < 0.05 (**Table 2** and **Table 3**). Also mean values of the isometric muscle power of the right quadriceps, strength of the right and left hand grip show significant reductions p-values < 0.05, whereas mean values of biceps and left quadriceps muscles show non-significant reductions p-

Table 2. Mean values of BMI, body composition, and VO_2 max pre- and post-surgery by three months

Variables	Patients of BS		p-value
	Pre	Post	
	M ± SD	M ± SD	
Wight in kg	109.25 ± 22.02	92.44 ± 17.49	< 0.001^{w*}↓
BMI in kg/m^2	43.12 ± 6.39	36.54 ± 5.08	< 0.001^{p*}↓
FM %	23.67 ± 5.59	18.53 ± 4.04	< 0.001^{p*}↓
FP %	54.26 ± 5.92	47.64 ± 14.10	0.002^{p*}↓
FFM %	19.38 ± 2.10	17.72 ± 1.62	< 0.001^{w*}↓
MM %	21.96 ± 5.89	19.22 ± 5.02	< 0.001^{w*}↓
VO_2 max ml/kg/min	19.54 ± 8.41	27.37 ± 7.63	< 0.001^{w*}↑

Note. ^{p}: Paired t-test was used for normally distributed variables; ^{w}: Wilcoxon signed ranks test was used for non- normal distributed variables; VO_2 max: Maximal capacity; *Significant differences p-value < 0.05; †: Non-significant differences p-value > 0.05; M: Mean; SD: Standard deviation; ↓: Reduction; & ↑: Increase

Table 3. Mean values of physical activity and isometric muscle power pre- and post-surgery by three months

Variables	Patients of BS		p-value
	Pre	Post	
	M ± SD	M ± SD	
Physical activities	576.0 ± 384.3	1,140.17 ± 894.20	< 0.000^{w*}↑
Rt hand grip (N/kg)	25.97 ± 13.29	23.67 ± 9.92	0.031^{w*}↓
Lt hand grip (N/kg)	23.10 ± 11.04	21.22 ± 9.73	0.014^{w*}↓
Rt biceps (N/kg)	9.09 ± 3.84	7.86 ± 2.23	0.322^{w†}↓
Lt biceps (N/kg)	9.58 ± 3.13	8.60 ± 2.22	0.198^{w†}↓
Rt quadriceps (N/kg)	14.76 ± 6.83	11.23 ± 2.83	0.045^{w*}↓
Lt quadriceps (N/kg)	13.95 ± 5.73	12.60 ± 4.76	0.208^{w†}↓

Note. Rt: Right; Lt; Left; ^{p}: Paired t-test was used for normally distributed variables, ^{w}: Wilcoxon signed ranks test was used for non-normal distributed variables; *Significant differences p-value < 0.05; †: Non-significant differences p-value > 0.05; ↓: Reduction; ↑: Increase; Pre: Baseline assessment; Post: Assessment after 3 months; *: p-value < 0.05 (significant difference); †: p-value > 0.05 (non-significant difference); N/kg: Newton per kilogram; M: Mean; & SD: Standard deviation

values > 0.05 (**Table 3**). In addition, the results show non-significant increases in mean values of all parameters of the pulmonary function test post-three months of BS p-values > 0.05 except significant increases in mean values for the predicated and absolute FVC_{max} where p-values were 0.001 and 0.003, respectively (**Table 4**).

Table 4. Mean values of pulmonary functions pre- and post-surgery by three months

Variables	Patients of BS		p-value
	Pre	Post	
	M ± SD	M ± SD	
FVC max predicate	83.04 ± 3.59	85.54 ± 2.41	0.001^{w*}↑
FVC max absolutely	2.92 ± 0.47	3.30 ± 0.54	0.003^{w*}↑
FEV1 predicate	81.29 ± 5.71	82.92 ± 5.55	0.056^{p†}↑
FEV1 absolutely	2.55 ± 0.58	2.68 ± 0.48	0.076^{w†}↑
FEV1\FVC ratio predicate	86.33 ± 7.03	87.42 ± 7.79	0.365^{w†}↑
FEV1\FVC ratio absolutely	85.87 ± 3.13	86.67 ± 2.49	0.326^{w†}↑
PEF predicate	82.46 ± 9.78	86.14 ± 11.52	0.063^{w†}↑
PEF absolutely	5.25 ± 0.80	5.71 ± 1.23	0.116^{w†}↑
MEF25 predicate	77.17 ± 16.21	84.25 ± 17.55	0.103^{w†}↑
MEF 25 absolutely	3.05 ± 0.77	3.30 ± 1.01	0.587^{w†}↑
MEF50 predicate	86.12 ± 21.31	93.37 ± 22.61	0.229^{w†}↑
MEF50 absolutely	3.69 ± 1.04	3.99 ± 1.18	0.252^{w†}↑

Note. FVC: Forced vital capacity; FEV_1: Forced expiratory volume in one second; FEV_1\FVC: Ratio of forced expiratory volume in the first second of expiration to forced vital capacity; PEF: Peak expiratory flow; MEF25: mean expiratory flow rate at 25%; MEF50: mean expiratory flow rate at 50%; ^{w}: Wilcoxon signed ranks test was used for non-normal distributed variables; *Significant differences p-value < 0.05; †: Non-significant differences p-value > 0.05; M: Mean; SD: Standard deviation; ↓: Reduction; & ↑: Increase

DISCUSSION

Obesity is a common health problem, it has negative impacts on different body systems. There are multiple therapeutic approaches for treating obesity, BS is a safe and effective method for rapid reduction of the body weight [59], it sometimes stays the optimum optional for treatment. Although BS has many advantages, it is associated with adverse effects. The current study aimed to investigate short term impacts of BS on exercise capacity, body composition, pulmonary functions, isometeric muscle power, strength of the hand grip, and physical activities after three months from surgery.

The current results show significant increases in VO_2 max in association with significant improvements in PA whereas significant reductions were obtained in FM, fat percentage, FFM, MM, and muscle strength. Our results of VO_2 max are supported with the findings in [6, 40, 41]. These improvements in VO_2 max after BS may be explained by physiological, environmental, behavioural factors [60], and other biomechanical, e.g., decreased joint pain and reduced intramuscular fat which is linked with poor physical function due to decreases in myokine secretion and increases in inflammatory adipokine interleukin-6 as well as psychosocial factors that play a role in improving patients'self-esteem [61]. On contrary to the current results, the findings in [28], were obtained reductions in VO_2 max after the third month from BS, this may be due to loss of blood from the gastrointestinal tract and/or mal-absorption or insufficient supplementation of iron, vitamin B9 or vitamin B12 (which are essential for erythropoiesis), these are the most frequent causes of anaemia after BS in addition, an excessive loss of muscle mass with its refection on the body's oxidative capacity [62].

One of the most critical outcomes for BS is the significant improvements of the body composition, which is the golden mark to emphasis success of baractric surgery. Our findings showed significant reductions in patients' BMI, body weight, FM, FFM, and MM at three months after surgery. This can be explained by the fact that after BS, patients must follow a structured dietary plan; firstly, a liquid diet is set that includes clear broths, sugar-free gelatin and protein shakes; secondly, the pureed food phase, patients consume soft, pureed foods such as mashed potatoes; thirdly, the soft food phase, patients can introduce soft foods such as canned fruits, cooked vegetables and fish; fourthly, involves a gradual return to regular food plan [20, 36]. As a result of limited consumed amount of food and malabsorption after BS, patients are instructed to consume protein and supplements to avoid a deficiency of proteins, vitamins B1, B12, and D, calcium, iron, zinc and copper [36]. The proteolysis process (i.e., breakdown of protein to amino acids) occurs to support metabolic cell functions and MM loss [20].

These significant observed reductions in FM, FFM, fat percentage, and MM may also be due to low caloric diet and food restriction that resulted from the surgery itself. At three months patients may still not have adapted for regular food intake, thus they may still have an issue with MM and FFM loss. The amount of weight lost after BS may be influenced by the

used surgical technique, e.g., size of the gastric pouch, alimentary limb length and gastrojejunostomy diameter [60].

BS also has several impacts on the musculoskeletal system which may be due to restricted food intake, micronutrient and macronutrient deficiency, and anatomical gastrointestinal tract changes; finally the resulting hormonal changes alter balance between bone formation and resorption, making bone weak and at risk of fracture [63].

Our results show our sample of patients with obesity apparently had normal pulmonary functions. These findings align with findings in [29], who reported that FEV_1 and FVC are slightly reduced in presence of obesity but that the FEV_1/FVC ratio is usually unaffected (results of pulmonary function test are affected if BMI > 62 kg/m^2). Although non-significant improvements in the patients' pulmonary functions test were obtained three months after BS, except FVC. These current findings disagree with results in [32, 33] in which it was found that FEV_1 and FVC significantly improved in patients after BS, also contradicted with findings in [31, 64], which gained significant improvements in all pulmonary functions parameters post BS. This may be due to marked significant reductions in body composition with its associated improvements in overall function including pulmonary function scores [65, 66].

The observed non-significant achievements of pulmonary functions in the current results may be due to pattern of the body fat distribution in our patients sample, it has a stronger association with pulmonary functions than with weight or BMI. It was suggested that abdominal obesity (male type) is strongly associated with respiratory function decline, possibly due to mechanical compression and obesity-induced airway inflammation [67]; thus, post-surgery weight reduction may have induced greater improvements in pulmonary functions, but majority of participants in the current study are females (peripheral pattern of obesity). It is also worth noting that participated patients needed more time to fully recover more than 3 months, those patients may have experienced respiratory muscle weakness after BS. Also, most of authors in previous studies evaluated pulmonary function after six months or one year after weight stabilisation. It was referred obtained improvements in lung volumes after BS to loss of MM [68]. In addition, it was concluded that severe obesity is linked with reductions in lung functions [69].

Our results show reductions in isometric muscle power three months after BS particular right quadricepes and strength of the right- and left-hand grip. Strength of the hand grip reflects the body's general condition, it is used as a new vital sign of health as its weakness is associated with morbidity, functional disability, and mortality in all population groups [70]. The current findings of the isometric muscle power align with the results in [61, 71]. Reductions in muscle power and presence of muscle atrophy after BS may be due to loss of FFM [22, 71], reduced type-I and type-II muscle fibres three months after surgery [22]. On contrary to our results findings in [24], which found unchanged of strength of hand grip after BS or metabolic surgery, even when there was reduced MM, also, it was obtained increases in isometric muscle power [20, 22], which may be due to they applied educational or exercise strengthing programs which is not the case in the current study (just evaluation not intervention), it was found that reductions in FM and FFM are strongly associated with improved respiratory muscle and reduced hand grip strength [71] while, it was detected reductions in MM that did not affect muscle power, thus the improvements in patients' VO_2 max, pulmonary functions, body composition, muscle strength and PA after BS may be due to impacts of the BS itself [72, 73].

Our results show significant improvements in PA. These findings agree with findings in [28], whereas disagree with findings in [74]; thus, PA should start once medical clearance is given [75]. It was recommended that starting of PA on same day of surgery, e.g., moving out of bed, walking a short distance, walking regularly after two weeks and returning gradually to different types of PA [76], also intense PA is needed to preserve muscular oxidative capacity, to stimulate muscular proteo-synthesis [62] and to improve muscle power [27].

However, after surgery, not all patients can follow the stander recommendations due to the nature of their conditions or associate challenges with undertaking considerable lifestyle changes. Adherence to exercise programs is a challenge for obese individuals due to many obstacles, e.g., low motivation, low self-efficacy, lack of scientific knowledge, lack of coping skills, reduced access to appropriate facilities, high costs of training programs, low social and cultural support and time conflicts [77]. Also, the obtained increases in both FM and MM loss after BS, were associated with lack of PA [78]. This explains the necessity of those patients for exercise professionalism, e.g., physical therapists and exercise physiologists. Physical therapists have the capabilities to evaluate lifestyle activities, body composition, physical fitness, to prescribe individualised rehabilitative programs, as well as to monitor patient's adherence during training [78].

CONCLUSION

Lifestyle modifications are the cornerstone for success of all outcome measures of weight loss after BS. Although achieved significant improvements in body composition including FM, percent of fat, FFM, MM, maximal exercise capacity, forced vital capacity, and PA after BS, those patients still need for early interventions with individualised rehabilitative training programs to improve their capabilities and general health.

Recommendations

Further studies are needed to investigate long-term impacts of BS on muscle power, different physical capabilities and cojnitive function. Establish rehabilitative training programs for obese patients before and after BS. Provide targeted patients with specific education programs and monitor their adherence to these programs with multidisciplinary professionals team members.

Limitations of the Study

VO_2 max was estimated with indirect method, majority of patients were female, lack of a prolonged follow-up, measurements of the total lung capacity and diffusing capacity for carbon monoxide not included.

Author contributions: SASA: participated mainly in conducting practical part of research and writing of the draft; **AAS:** formulated the idea of research, writing of the results and discussion, and did the statistical part, review, material, and methods; **MEA:** wrote and revised the manuscript; **EFY:** wrote the results and discussion and did the statistical part and review; & **AJA-A:** recruited the patients and wrote data. All authors have agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Acknowledgments: The authors would like to thank the head of the Department of Physical Therapy and the dean of scientific research at Imam Abdualrahman Bin Faisal University, Dr. Belal Elsayed Shanb, and Almoosa Specialist Hospital for their cooperation and assistance in conducting this research.

Ethical statement: The authors stated that the study was approved by the Institutional Review Board at Imam Abdulrahman Bin Faisal University (IRB-PGS- 2022-03-364) and the Research Center at Almoosa Specialist Hospital (ARC-22.11.05) on 4 October 2022. Informed consent was obtained from every participant. The ethical guidance for this study is based on the Helsinki Declaration, and all data are kept confidential. This study was conducted in accordance with international criteria for scientific research.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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