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ORIGINAL ARTICLE

Effects of a Multi-Component Exercise Program and Bariatric Surgery on Anthropometric Characteristics and Physical Function in Patients with Obesity

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ABSTRACT

Background. Obesity is considered a major global public health issue. Interestingly, physical exercise has a vital role in preventing, managing, and treating obesity. However, bariatric surgery has been reported as an effective treatment option. **Objectives.** The present trial aimed to investigate the effectiveness of a 6-month, real-world, multi-component exercise intervention with bariatric surgery to improve anthropometric and physical function parameters in individuals with obesity. **Methods.** Seventy-one individuals (73% female, mean age: 39.7±20.3 years) with obesity (mean body mass index: 38.4±3.0 kg/m^2) were recruited, and 69 completed the study. Participants were divided into i) exercise group (EX, n=25; randomly assigned), ii) bariatric surgery group (BS, n=23; group-randomized), and iii) non-exercise and non-surgical control group (C, n=23; randomly assigned). Anthropometric parameters, handgrip strength, functional aerobic capacity, and flexibility were assessed at baseline and after six months. **Results.** The EX and BS groups experienced beneficial changes in anthropometrics, functional aerobic capacity, and flexibility compared with C ($p<0.001$). BS demonstrated greater improvements in anthropometrics and functional aerobic capacity than C ($p<0.05$), while EX showed higher increases in handgrip strength than BS ($p<0.05$). Also, moderate negative and positive associations were found between anthropometrics and physical function changes in EX and BS, respectively. **Conclusion.** A multi-component exercise programming approach could enhance physical capabilities. At the same time, bariatric surgery improved anthropometric characteristics, suggesting that surgical interventions may improve body composition but not muscular fitness in individuals living with obesity.

KEYWORDS: ***Obesity, Physical Function, Anthropometric Characteristics, Weight Loss, Muscular Strength, Cardiorespiratory Fitness, Flexibility.***

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INTRODUCTION

Obesity is a chronic condition characterized by several comorbidities caused by genetic, metabolic, environmental, and behavioral variables (1). Every year, at least 2.8 million persons perish from obesity-associated disorders worldwide, making obesity a major public health issue (2, 3). Among the treatment options, bariatric surgery is the most successful, resulting in significant weight reduction and a potential gain in functional capacity (4, 5). Health-related behavioral change, mainly focusing on an active lifestyle, has been documented as the optimal anti-obesity strategy (6-8). However, bariatric surgery has also been reported as an effective option for people with obesity, even if significant clinical outcomes cannot always be attained (9, 10). Interestingly, long-term behavioral-related improvements are critical for overcoming weight regain, supporting post-surgery mental health, and enhancing metabolic health in bariatric surgery patients (11, 12).

Weight-loss surgery, also known as bariatric surgery (13), encompasses procedures that alter the digestive system to aid in weight reduction. Some procedures restrict food and liquid intake, inducing a quicker feeling of fullness, while others modify the small intestine's ability to absorb nutrients, thereby reducing calorie absorption. These surgical interventions may also influence hormones and gut bacteria, potentially reducing appetite and enhancing insulin sensitivity and fat metabolism (14). Bariatric surgery procedures vary; among the most commonly performed are the gastric sleeve and the Roux-en-Y gastric bypass, which were applied to our patients in this study.

Physical activity is a crucial component of lifestyle therapy for weight loss (15). Particularly, physical activity increases functional ability and reduces the risk of metabolic illnesses through various mechanisms, including lowered body weight, total body fat, and visceral fat, according to non-surgical weight loss research (9, 16, 17). Although physical exercise alone may not result in clinically meaningful weight loss, it protects lean mass throughout weight loss, which may lead to a more desired body composition outcome (18, 19). Physical exercise comes in a wide variety, offering a broad range of health advantages, such as the ability to control weight, prevent diseases (e.g., type 2 diabetes, pulmonary diseases, cardiovascular disease, and various types of cancer), increase strength, and endurance, improve flexibility and strength, support bone health, elevate mood, and lengthen life (20). Also, exercise training is feasible and acceptable for individuals with obesity awaiting or having undergone bariatric surgery (21). Consequently, an active lifestyle is necessary to maximize and sustain weight management after bariatric surgery.

However, there is a paucity of experimental data regarding the effects of physical activity and supervised exercise on obesity-related outcomes in a population with obesity (12). It is important to include exercise professionals in the multidisciplinary team for obesity treatment (22). Importantly, progression, individualization, and health appraisal are essential considerations when designing exercise programs for people living in larger bodies (23). In general, exercise training at any intensity should be performed daily to avoid several illnesses and other health problems (24-28). However, people with excess weight are likely to present with insufficient physical activity levels and exercise motivation due to body dissatisfaction and poor mental health (29). Interestingly, exercise programs for weight loss promoting health and fitness benefits in individuals with excessive weight and potential metabolic dysregulation have been reported as some of the most popular options among practitioners in the exercise community worldwide (30). Specifically, both traditional (e.g., aerobic and resistance training) and alternative exercise modes (e.g., high-intensity interval training [HIIT], Pilates, and yoga) appear to elicit positive alterations in people with overweight/obesity (31-36). It has been well documented that increasing physical activity levels following bariatric surgery may induce greater improvements in body mass and mental health (37, 38). Nevertheless, inconsistency is present in the current literature regarding the vital role of exercise in bariatric surgery patients due to great methodological diversity (39).

To date, no relevant studies provide data regarding the comparison between regular physical exercise and bariatric surgery among individuals with obesity. Thus, the primary aim of the present trial was to investigate the effects of a real-world, multi-component exercise intervention on anthropometric characteristics and physical function parameters with bariatric surgery in individuals living with obesity and obesity. The secondary aim was to examine associations between anthropometric and physical function outcomes. It was hypothesized that a hybrid training exercise protocol of a higher vs. lower number of weekly training sessions would elicit benefits of a similar magnitude. We also hypothesized that the involvement in physical exercise would elicit more significant improvements in the selected outcome measures among individuals living with obesity and obesity compared with bariatric surgery and control groups.

MATERIALS AND METHODS

Study design. The study was carried out in the United Arab Emirates in cooperation with a higher educational institution and two local hospital clinics for obesity treatment. An invitation announcement was sent to hospital clinics and educational institution communities, inviting subjects living with obesity to participate in this study. Both clinics collaborated to explain the protocol and facilitate communication with the researcher. All activities, including announcement, recruitment, pre-participation screening, allocation, intervention, measurements, and data collecting, took place between January 2022 and April 2023. The Institutional Survey and Ethics Review Committee examined and approved methods on February 11th, 2020, with a letter signed by the committee chairman, procedures, and ethics according to the Standard Protocol Items: Recommendations for International Trials (ref. no. SRC11022020 approved on February 11, 2020) (40). All data collected were confidential, and access was provided exclusively to researchers.

A pragmatic, partially randomized preference design was used since this is considered a standard methodological approach when patients with a strong preference may not be willing to be randomized. In particular, this approach allowed patients who were unwilling to be randomized but willing to state their preference to receive their preferred treatment instead of randomization. Initially, individuals who met the inclusion criteria and volunteered to participate in the study underwent baseline assessments, including anthropometric and physical function indices. After that, individuals scheduled to have their bariatric surgery within two months following the recruitment formed the bariatric surgery group (BS); thus, they were group-randomized, aiming to avoid loss of ethics (41). The remaining were randomly assigned to either an exercise group (EX) or a control group (C) using the computer software program www.randomizer.org (assessed in February 2022). EX was supervised by the principal investigator for six months and performed a multi-component program four days weekly in a real-world gym setting. In BS, baseline assessments were conducted one week before the operation. C did not follow any structured exercise or receive bariatric surgery throughout the six-month intervention. Outcome variables were tested at baseline and after six months (post-testing). At post-testing, all assessments were performed in the morning, five days after the last exercise session for EX, and six months following the operation for BS. All assessments were conducted by the same assessor, blinded to group allocation. All participants were encouraged to maintain their habitual physical activity and eating patterns throughout the intervention.

Participants. Based on training studies recruiting individuals with obesity (42, 43), a preliminary power analysis (effect size >0.55, probability error of 0.05, two-tailed alpha level, power of 0.9) using the G*Power 3.1.9.2 program for three groups and two measurement points, and accepting a potential dropout rate of 30%, estimated that a sample of 20–22 participants per group was necessary to identify statistically significant trial effects. Printed leaf-lets and word-of-mouth strategies were used to recruit volunteers based on the following inclusion criteria: 1) age of 18–55 years; 2) obesity ≥30 kg/m^2; 3) no participation in any structured exercise training program for at least six months before the study; 4) no use of diet, supplementation or medication before (≥6 months) and during the study; 5) no weight loss of >10% of body mass before (≤6 months) the study; and 6) absence of any physiological or psychological disorders. Figure 1 shows the process with the number of participants from selection till data completion. Volunteers were excluded from the study if, during the intervention, they: 1) missed ≥20% of total prescribed exercise sessions (for the exercise group); 2) adhered to a nutritional intervention (for all groups); and 3) participated in any unassigned exercise (for all groups). Participants received written and verbal information about the research procedures and potential inherent risks and benefits. Volunteers signed a written informed consent, and the principal investigator answered all relevant questions. Table 1 shows the participants' characteristics.

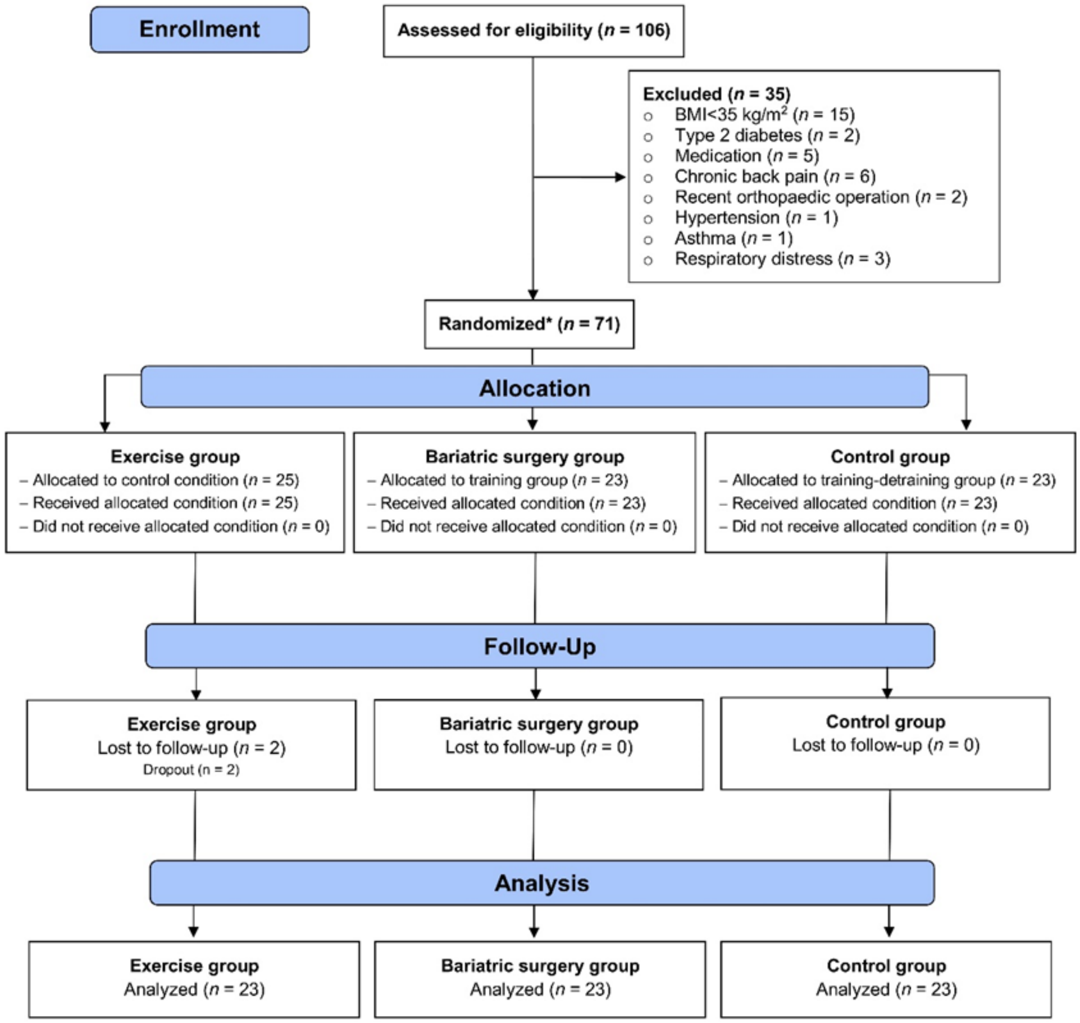

Figure 1. Flow diagram of the study. *Partially randomized preference trial (participants in the exercise and control groups were randomly assigned, while participants in the bariatric surgery group were randomized by group).

Table 1. Baseline characteristics of the participants

	EX	BS	C	*P*
Gender				0.781
Male, *n* (%)	4 (17.4)	6 (26.1)	7 (30.4)	
Female, *n* (%)	19 (82.6)	17 (73.9)	16 (69.6)	
Age (years)	33.1±11.9	36.1±12.6	33.2±11.7	0.674
Body mass (kg)	99.5±15.8	110.4±19.3	100.9±16.4	0.068
Body height (m)	1.63±0.07	1.64±0.07	1.65±0.09	0.839
BMI (kg/m^2)	37.2±3.1	40.9±3.7	37.0±2.2	0.014

Values are expressed as mean±SD. BMI: body mass index, BS: bariatric surgery group, C: control group, EX: exercise group.

Exercise training protocol. After baseline assessment, the EX group followed a six-month exercise training program. The assigned exercise sessions were based on a progressive, multi-component programming approach including various moderate- to vigorous-intensity training modalities adapted for people with excessive weight, such as i) hybrid-type, neuromuscular interval training implementing bodyweight exercises with accessory functional training equipment in a progressive way twice weekly, ii) Pilates mat work with props (balls and elastic bands) once weekly, and iii) mixed workouts consisting of a 20-min stretching component followed by a 30-min self-selected exercise component, choosing among yoga, dance aerobics, and small-sized games (e.g., football, basketball, and volleyball). Adequate physical activity levels have been demonstrated to markedly enhance body weight, fat composition, and overall health risks. Typically, physical activity yields a modest impact on body weight, usually amounting to 3% or more, if combined with diet, of the initial body weight (22). All exercise sessions were conducted in a real-world gym setting under normal temperature for indoor exercise (20°–22°C). Participants joined the exercise sessions at least three times per week on nonconsecutive days, performing full-body routines to activate all muscle groups while combining cardiorespiratory and musculoskeletal stimuli every week. The modified Borg Dyspnea Scale was used to rate the perceived exertion (RPE), encouraging values between 4 and 6 on a 0–10 scale (44). Also, participants were instructed on how to use manual palpation to self-monitor exercise heart rate three to four times during all sessions, ensuring moderate- to vigorous-intensity [65%–75% of the maximum heart rate (MHR)] for this cohort (45).

Measurements.

Anthropometric characteristics. Height and body mass (BM) were measured to the nearest 0.1 cm and 0.1 kg, respectively, using a beam scale (SECA 700, Hamburg, Germany). The body mass index (BMI) was calculated using the equation: BMI = [body weight / (height × height)]. Waist (WC) and hip (HC) circumferences were measured using a Gulick II Plus tape measure (model 67020), and the waist-to-hip ratio (WHR) was calculated as reported (46).

Physical function. Muscular fitness was assessed by evaluating handgrip strength (HGS) using a hydraulic hand dynamometer (Jamar 63785, Anaheim, CA, USA). The participant squeezed the dynamometer with all their strength. This isometric test was performed three times with each hand. An average score was then calculated using the measurements from both hands according to standard procedures (47).

Cardiorespiratory fitness was evaluated using the six-minute walk test (6MWT), a simple test that does not require specialized equipment or considerable clinician training. It assesses an individual's submaximal level of functional ability while walking for 6 minutes on a flat, hard surface, measuring the total distance in meters in a 6-minute time frame. Participants were advised to walk as far as possible for 6 minutes, the distance (a 30-m unimpeded walkway) was marked using two cones, while chairs were placed on either side and halfway along the walking stretch (48).

Flexibility was assessed using the sit and reach test (SRT), a commonly used test that evaluates the flexibility of a person’s lower back and hamstring muscles; it is an easy test that can be conducted everywhere and is the optimal option to evaluate the hamstrings' flexibility, and it is widely used as a broad measure of adaptability. The persons being tested sat down and stretched their arms forward slowly with straight knees while breathing normally. They put one hand on the other with their palms facing down and reached as far as they could, holding that position for about two seconds. The score was the farthest point they could reach on the floor and the box with their fingertips. Participants performed both tests three times, and the scores were recorded as the average. They were asked to breathe normally and not hold their breath at any time (49).

Statistical analyses. The Shapiro-Wilk test was used to verify data normality. Groups were compared at each time point using a one-way analysis of variance (ANOVA) with a Tukey post-hoc analysis. Within-group differences were analyzed using the paired samples t-test. For the description of demographic and other categorical variables, frequencies and percentages were used, while mean values and standard deviations were used for the description of quantitative variables. Eta squared was used to calculate effect sizes (ES). The latter was interpreted as small, medium-sized, and large for values 0.01–0.05, 0.06–0.13, and ≥0.14, respectively (50). In all analyses, a confidence interval of 95% was considered. Pearson’s correlation coefficient was used to examine the association between anthropometrics and physical function outcomes in EX and BS. Statistical significance was set at $p<0.05$. Data were analyzed using the SPSS 26.0 software (IBM Corp., Armonk, NY, USA).

RESULTS

Initially, 106 volunteers were interviewed, and 71 (52 females and 19 males) aged 18–55 years (mean age: 39.7±20.3 years) met the inclusion criteria and completed the study (Figure 1). Participants were divided into three groups: i) exercise group (EX, n=25), ii) bariatric surgery group (BS, n=23), and iii) non-exercise and non-surgical control group (C, n=23). Of the 71 eligible participants, 23 were scheduled to have their bariatric surgery in the following two months of the recruitment, and, thus, they were group-randomized, aiming to avoid loss of ethics (41). The remaining 48 participants were randomly allocated to the EX and C groups. The overall exercise group dropout rate was 3% (2/71). 2 participants dropped out from the exercise group, the dropout rate was 8% (2/25), and the attendance rate was 88%. At baseline, significant differences were found in BMI (p=0.014, ES=0.117, with means 40.9±3.7 and 37.2±2.2) and 6MWT (p<0.05, ES=0.123) between EX and BS as well as C; these differences were expected as candidate patients for bariatric surgery can be approved for surgery having a BMI of 35% and above without comorbidities (51). For EX and BS, changes were found in all variables in time (p<0.05) except WHR. No differences were detected in all variables in time for C. Within- and between-group changes in all outcome measures are shown in Table 2.

Table 2. Changes in all outcome measures throughout the intervention

Variables	EX		BS		C	
	Pre	Post	Pre	Post	Pre	Post
BM (kg) * ‡ †	99.5±15.8	89.1±13.2 §	110.4±19.3	85.4±15.3 §	100.9±16.4	100.7±16.3
BMI (kg/m^2) * ‡ † ^	37.2±5.1	33.1±2.3 §	40.9±5.7	31.7±3.8 §	37.0±4.2	37.0±3.4
WC (cm) * ‡ †	105.2±13.2	97.2±8.3 §	114.4±16.0	97.4±9.0 §	108.6±14.7	108.5±13.5
HC (cm) * ‡ †	122.0±8.5	114.1±4.3 §	130.1±16.3	113.8±8.8 §	119.6±13.7	119.8±14.6
WHR	0.86±0.10	0.85±0.05	0.88±0.08	0.86±0.03	0.91±0.07	0.91±0.10
R-HGS (kg) * ‡ @	19.64±7.33	22.68±11.22 §	21.48±7.93	17.18±4.63 §	25.70±9.40	26.35±11.08
L-HGS (kg) * ‡ @	19.86±6.70	22.36±9.87 §	20.48±7.85	16.78±4.24 §	24.87±10.04	24.52±8.12
6MWT (m) * † @	449.2±96.0	535.3±38.3 §	383.2±84.4	500.6±46.2 §	383.5±75.3	398.6±23.0
SRT/box (cm)	-4.32±12.26	-0.28±4.03 §	-5.30±7.28	-1.04±2.05 §	-5.87±9.22	-5.91±0.47
SRT/floor (cm)	-7.08±11.85	-1.69±5.30 §	-9.52±8.93	-4.13±2.97 §	-8.83±10.50	-8.57±0.92

BS: bariatric surgery group, C: control group, EX: exercise group, BM: body mass, BMI: body mass index, WC: waist circumference, HC: hip circumference, WHR: waist-to-hip ratio, R-HGS: right-hand grip strength, L-HGS: left-hand grip strength, 6MWT: six-min walk test, SRT: sit and reach test. *: C vs. EX at post (p<0.05), ‡: C vs. BS at post (p<0.05), †: EX vs. BS at post (p<0.05), §: Post vs. Pre (p<0.05), ^: BS vs. C and EX at Pre (p<0.05), @: EX vs. C and BS (p<0.05).

Anthropometrics. At post-training, EX and BS provoked reductions by 10.4% and 22.7%, respectively, in body mass (BM) compared with C (p<0.001, ES=0.166). EX and BS demonstrated reductions by 10.3% and 22.6%, respectively, in BMI compared with C (p<0.001, ES=0.862), while BS showed a greater reduction in BMI than EX (p=0.025, ES=0.862). In WC, EX and BS induced beneficial alterations by -7.7% and -14.8%, respectively, compared with C (p<0.001, ES=0.667), while BS exhibited a statistically significant reduction in WC compared to EX (p=0.032, ES=0.667). In HC, EX and BS elicited changes by -5.9% and -12.5% compared with C (p<0.001, ES=0.658), respectively, while BS exhibited a reduction in HC compared with EX (p=0.038, ES=0.658). As for WHR, no differences were found among groups throughout the intervention.

Handgrip strength. A difference was found in the right hand (R-HGS) between EX (+15.5%) vs. BS (-20.1%) and C (+2.5%) (p<0.001, ES=0.507), while EX demonstrated an increase in R-HGS compared with C (p=0.001, ES=0.507), at post-training. In the left hand (L-HGS), a change was detected between EX (+12.6%) vs. BS (-18.3%) and C (-1.4%) (p<0.001, ES=0.432).

Functional aerobic capacity. In 6MWT, BS, EX, and C demonstrated increases of 30.6%, 19.2%, and 3.9% throughout the intervention (p<0.001, ES=0.582), respectively, while BS showed a greater improvement than EX (p=0.043, ES=0.582), at post-training.

Flexibility. At post-training, EX and BS showed alterations by 93.5% and 80.4% compared to C (-0.7%) in the SRT on the box, respectively (p<0.001, ES=0.327). In SRT on the floor, EX and BS showed improvements by

83.8% and 56.6%, respectively, compared with C (+2.9%) (p<0.001, ES=0.327).

Correlations. In EX, correlational analyses indicated moderate negative relationships (r=0.419–0.674, p<0.05) among anthropometrics and physical function parameters. Most associations were detected among anthropometric characteristics (e.g., BM, BMI, WC, and WHR) and SRT. In BS, moderate positive associations were found between BM and HGS changes (r=0.399–0.461, p<0.05), WC and HGS (r=0.556–0.614, p<0.01), and WHR and all physical function parameters (r=0.455–0.600, p<0.01), except 6MWT. No associations were observed between HC and physical function alterations in BS post-training. Table 3 details all correlations found among anthropometrics and physical function outcomes.

Table 3. Pearson correlations among anthropometrics and physical function outcomes

Variables	EX					BS				
	R-HGS	L-HGS	6MWT	SRT/box	SRT/floor	R-HGS	L-HGS	6MWT	SRT/box	SRT/floor
BM	–	–	–	-0.558**	-0.465**	0.399*	0.461*	–	–	–
BMI	–	–	–	-0.419*	–	–	–	–	–	–
WC	–	-0.470*	–	-0.560**	-0.483*	0.614**	0.556**	–	–	–
HC	–	–	-0.479*	–	–	–	–	–	–	–
WHR	-0.560**	-0.674***	–	-0.462*	-0.427*	0.600**	0.561**	–	-0.455*	-0.528**

BS: bariatric surgery group, EX: exercise group, BM: body mass, BMI: body mass index, WC: waist circumference, HC: hip circumference, WHR: waist-to-hip ratio, R-HGS: right-hand grip strength, L-HGS: left-hand grip strength, 6MWT: six-min walk test, SRT: sit and reach test. *: p<0.05, **: p<0.01, ***: p<0.001.

DISCUSSION

Main results in brief. This partially randomized preference trial compared the impact of a multi-component exercise programming approach vs. bariatric surgery and controls among previously inactive individuals with severe obesity. It revealed a significant reduction in BMI across the EX and BS groups. Although BS had a double mean weight loss (-9.27 kg) than EX (-4.06 kg), it still indicates individuals with severe obesity can effectively manage their weight through both interventions. Interestingly, moderate negative relationships between anthropometrics and physical function outcomes in EX were found. In contrast, moderate positive correlations were detected among various anthropometrics (e.g., BM, WC, and WHR) and handgrip strength changes, and moderate negative correlations were observed between WHR and SRT in BS.

Current knowledge. Bariatric surgery, also known as "weight-loss surgery", refers to a range of procedures that modify the digestive system to help consume weight by reducing the number of calories the body can absorb. Such a medical operation may have an impact on hormones or bacteria in the digestive tract, which might decrease appetite and hunger and enhance how the body uses insulin and metabolizes fat, resulting in quick and high weight loss (52-54). On the other hand, exercise programs are proposed as an option for those individuals living with severe obesity, but not fulfilling the criteria to undergo bariatric surgery, as BMI rate should not be the only criterion (55). This finding has direct implications for everyday life, as it suggests that individuals living with severe obesity can achieve a healthier body weight, reducing the risk of obesity-related illnesses, such as type 2 diabetes, hypertension, metabolic syndrome, cardiovascular disease, joint disorders, and various types of cancer. Combined physical exercise and bariatric surgery are collectively recommended for ultimate results (9), and our study aligned with previous trials regarding BMI reduction through structured exercise (56-59) and bariatric surgery (60, 61).

Anthropometric characteristics. Although pharmacotherapy has achieved impressive results regarding weight loss in recent years and can be an alternative obesity therapy for patients who cannot fulfill the criteria of surgery, better results are optimized when associated with behavioral changes such as physical activity and a healthy lifestyle (6-8). Even when surgery is successful, not all patients obtain the anticipated clinical outcomes (9, 10). Aside from the type of bariatric surgery, patients' behavioral modifications, such as physical activity, impact on post-surgery outcomes (11). Weight loss following bariatric surgery may persist for up to two years (12, 15). Weight regain occurs at varied rates and is influenced by behavioral factors (12) since poor diet quality, nutritional monitoring, and sedentary behavior are drivers of weight regain (16). Also, metabolic risk variables are improved during the treatment, while physical activity and exercise aid in long-term management (17). However, evidence purely based on observational studies indicated that increasing physical activity after bariatric surgery related to higher weight loss and health-related quality of life (38, 39), but several randomized controlled trials produced inconsistent results. This discrepancy can be attributed to the difficulties in determining the exact dose-response effect of the treatment since the patient's actual health status (physical condition, diseases, and medications) can be so different that its extra effects on health show too much variation (37, 62). Collectively, bariatric surgery provides rapid weight loss because of drastically reduced daily caloric intake. Thus, patients present with significantly improved anthropometrics within 6 months following an operation. On the other side, physical exercise alone cannot induce similar energy expenditure among people with obesity compared to what is observed in bariatric surgery patients due to the substantial changes in dietary patterns.

Physical function. The improvements in physical function, including muscular strength, cardiorespiratory fitness, and flexibility, were significant in EX, along with BMI, handgrip strength, lower back and hamstring flexibility, and walking distance improvement, underscored the significance of regular exercise for enhancing daily functioning, this agreed with the outcomes of a study conducted in females living with abdominal obesity that followed a 3-month exercise program for three times a week. The results were significant regarding endurance, strength, and physical capacity (24). Both EX and BS groups had almost the same improvement in walking distance; however, BS showed greater improvements, accomplishing a greater distance in the 6MWT assessment compared with EX (117.4 vs. 86.1 m). As for flexibility, EX and BS demonstrated similar improvements compared with controls. This finding can be justified as weight loss was greater in BS, leading to better results in the waist and hip circumferences and better reaching out on the box and the floor. In general, people exhibit beneficial alterations in body functionality after weight loss from both cardiorespiratory and musculoskeletal standpoints. In general, people exhibit beneficial alterations in body functionality after weight loss from both cardiorespiratory and musculoskeletal standpoints. This can be explained by the fact that individuals struggling with weight-bearing movements can address better not only activities of daily living but also exercise training-related tasks after a meaningful weight loss. Hence, post-bariatric surgery patients showed considerable improvements in aerobic capacity, mobility, and functionality in the present study. However, conflicting results are currently present regarding the impact of bariatric surgery on functional aerobic capacity and musculoskeletal fitness in people with a BMI exceeding 35 kg/m^2 (63-65).

Stronger hands and improved walking capacity translate into improved physical independence and a higher quality of life, as proved in the current study. This result can mean increased mobility, the ability to engage in daily activities easily, and a reduced risk of falls, particularly in older adults. These findings are supported by Jiang et al. (66), who, in alignment with our results (67), concluded that a loss of 10% and higher total weight can improve physical function. BS fell behind in improving strength in both hands as measured in the hand grip, and that is probably because of lean body mass loss after surgery, as extensively reported (68-70). Thus, exercise training has been strongly recommended to patients undertaking bariatric treatment in the pre- and post-operative time, as it contributes further to weight loss management (38, 71). The improvements in physical function, particularly in hand strength and walking distance, emphasize the potential benefits of exercise in enhancing individuals' functional capacity. Notably, the positive outcomes in hand strength and walking distance for EX indicate that structured exercise programs can lead to physical function improvements in people with severe obesity. The minor to least change in physical function in the control group suggests that standard care alone may have limited effectiveness in achieving substantial weight reduction over a short-term period.

Nevertheless, some recent studies report different results. Regarding physical function, among 62 patients who were assessed post-bariatric surgery, improvements in muscle strength and functional capacity were found six months after surgery, with no sarcopenia found among them (72). Sarcopenia is not necessarily an indication of lower physical function when obesity is absent, but, when it exists, the odds of having more difficulty in physical performance are higher (73). Oppert et al. (74) evaluated muscle mass improvement post-operation, comparing three groups of 73 female patients, randomly allocated to protein intake, supervised strength training, and protein intake, and the control group of only normal care. They concluded that muscle loss post-bariatric surgery can be treated with exercise and protein intake. One study observed no change in hand grip strength and overall lean mass reduction four months post-operation in 25 patients who underwent bariatric surgery (75).

A higher 6MWT distance before surgery has been linked to early weight reduction following surgery (76, 77). Along with a negative correlation between greater BMI and 6MWT results, dyspnea and musculoskeletal discomfort are more common in individuals living with severe obesity, and the 6MWT distance results tend to decline in these patients (78). The present findings showed a negative association between anthropometrics and physical function in EX. Conversely, a positive association between anthropometrics and handgrip strength and a negative association were found between WHR and flexibility in BS. Such observations support the evidence on the negative role of bariatric surgery in muscular fitness (68-70), but not flexibility while strengthening the favorable alterations in physical fitness among individuals with severe obesity engaging in long-term exercise interventions without involvement in a bariatric surgery treatment. In summary, the present findings have clinically relevant implications for everyday life and general health, suggesting that individuals with severe obesity have effective treatment options, including physical exercise and bariatric surgery, to manage their weight and improve physical function and well-being.

Limitations. The present study has several limitations. First, a partially randomized preference design was used to overcome ethical issues related to medical treatment allocation in obese individuals at the cost of potentially introducing bias in estimating the effects of interest (79). Second, the lack of assessment of habitual physical activity levels and eating patterns (only an interview was used) throughout the intervention is an additional limitation affecting the interpretation of the current results, given that combined physical exercise and diet can improve cardiometabolic health-related indices among people with obesity (80). Third, body composition measurements were not conducted to support the present results related to anthropometric parameters among individuals with severe obesity. Finally, the long-term effects of each intervention were not evaluated.

Directions for further research. Our study encourages further research with long-term follow-up trials to assess the sustainability of the improvements in anthropometrics, physical function, and cardiometabolic and mental health following multi-component exercise programs, as previously reported (81-84). Moreover, it calls to explore cost-effectiveness by conducting economic evaluations to determine the cost-effectiveness of different obesity treatments and assessing the long-term economic impact of treatments on healthcare utilization and productivity. Nowadays, with all the weight loss medication treatments available, there is a need to assess the combination of exercise intervention with obesity treatment medications and explore their impact and sustainability of outcomes. These research directions can advance our understanding of obesity management and inform evidence-based practices for improving the health and well-being of individuals living with obesity, especially those following bariatric surgery (85). Also, biochemical measures should be included in future studies investigating the comparison between bariatric surgery and multi-component exercise interventions since various types of exercise induce beneficial changes in glucose and lipid metabolism (37, 86, 87), while relevant data for the role of bariatric surgery are limited. Additionally, interdisciplinary collaboration between researchers, clinicians, psychologists, and exercise experts can contribute to comprehensive and holistic approaches to obesity care since such a strategy may support the Exercise is Medicine initiative recently reported as one of the top trends in the health and fitness sector (88).

CONCLUSION

Exercise and bariatric surgery interventions resulted in a reduction in BMI over six months, with exercise showing a more moderate decrease and bariatric surgery leading to a more substantial reduction in individuals with severe obesity. This outcome indicates that both interventions can be effective in addressing obesity-related weight concerns. However, bariatric surgery had an impact on anthropometric characteristics, suggesting that it may improve body composition. On the other hand, exercise intervention improved physical function, including hand grip strength and walking endurance. This outcome implies that structured exercise programs can enhance physical capabilities without substantial weight loss. The findings of the present study can support medical and exercise professionals in promoting the vibrant role of multi-component exercise programming in provoking major health and fitness benefits among people with severe obesity.

APPLICABLE REMARKS

- Bariatric surgery shows a greater influence on anthropometrics than the multi-component exercise program in adults living with obesity.
- A multi-component exercise program shows greater improvements in muscular fitness among individuals with obesity.
- Clinicians and practitioners should promote multi-component exercise programs to their patients with obesity to achieve not only weight loss goals but also physical performance ones.

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AUTHORS' CONTRIBUTIONS

Study concept and design: Marilyn Gilyana, Evangelia Kouidi. Acquisition of data: Marilyn Gilyana. Analysis and interpretation of data: Marilyn Gilyana, Evangelia Kouidi, Alexios Batrakoulis, Sameer Badri Al-Mhanna. Drafting the manuscript: Marilyn Gilyana, Alexios Batrakoulis. Critical revision of the manuscript for important intellectual content: Marilyn Gilyana, Alexios Batrakoulis, Dimitrios G. Goulis, Konstantina Symeonidou, Sameer Badri Al-Mhanna, Evangelia Kouidi. Statistical analysis: Marilyn Gilyana, Alexios Batrakoulis, Sameer Badri Al-Mhanna. Administrative, technical, and material support: Marilyn Gilyana, Evangelia Kouidi, Dimitrios G. Goulis, Konstantina Symeonidou. Study supervision: Evangelia Kouidi.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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