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Clinical Research Article

One Year Changes in Body Composition and Musculoskeletal Health Following Metabolic/Bariatric Surgery

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Abstract

Context: There are limited comparative studies between one-anastomosis gastric bypass (OAGB) vs Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG) on body composition and musculoskeletal health.

Objective: To compare changes in body composition, areal bone mineral density (aBMD), muscle strength, and physical function in the first year following OAGB, RYGB, and SG within a UK-based healthcare setting.

Methods: This is a secondary analysis of the BARI-LIFESTYLE trial in 119 adults (77% women; mean ± SD age 45.9 ± 10.3 years; body mass index 43.6 ± 5.5 kg/m^2) who underwent OAGB (n = 19), RYGB (n = 39), and SG (n = 61). Body composition and aBMD by dual energy x-ray absorptiometry, handgrip strength, sit to stand (STS) test and 6-minute walking test (6MWT) were assessed presurgery and at 12 months postsurgery.

Results: OAGB, RYGB, and SG exhibited similar reductions in body weight, body fat, and lean mass (within-group comparisons, $P < .001$). All surgery types were associated with reductions in aBMD at the total hip, femoral neck, and lumbar spine, which were more pronounced after OAGB and RYGB than after SG (all $P < .03$), though there was no difference between OAGB and RYGB. Despite reductions in absolute handgrip strength, relative handgrip strength, STS test, and 6MWT improved postsurgery (all $P < .02$), with no differences by surgical procedure.

Conclusion: OAGB, RYGB, and SG resulted in comparable weight loss, changes in body composition and improvements in relative muscle strength and physical function. OAGB and RYGB, compared with SG, led to greater BMD reductions at clinically relevant sites. Future long-term studies should explore whether these BMD reductions translate into a greater fracture risk.

Key Words: metabolic/bariatric surgery, weight loss, body composition, bone mineral density, muscle strength, physical function

Abbreviations: %WL, percentage weight loss; 6MWT, 6-minute walking test; aLM, appendicular lean mass; aBMD, areal bone mineral density; BMI, body mass index; DXA, dual energy x-ray absorptiometry; GLP-1RA, glucagon-like peptide-1 receptor agonist; HRT, hormone replacement therapy; MBS, metabolic/bariatric surgery; MCID, minimal clinically important difference; OAGB, one-anastomosis gastric bypass; RCT, randomized controlled trial; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; STS, sit to stand; UCLH, University College London Hospitals; VAT, visceral adipose tissue.

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Metabolic/bariatric surgery (MBS) leads to marked and sustained weight loss, along with the improvement or resolution of obesity-linked comorbidities (1). Sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) are currently the 2 most commonly performed MBS in the UK and globally (2), and their impact on weight loss and various health outcomes has been widely studied (3, 4). More recently, one-anastomosis gastric bypass (OAGB) has emerged as the third most commonly performed surgery (2). This is attributed to OAGB being technically easier to perform, with a potentially better safety profile than RYGB, while still producing weight loss outcomes comparable with both RYGB and SG (5). Indeed, according to the latest data from the UK National Bariatric Surgery Registry, the percentage weight loss (%WL) at 1 year postsurgery is 33.7% for OAGB, 32.9% for RYGB, and 29.2% for SG (6).

It is known that the substantial weight loss constitutes not only fat mass but also fat-free mass including bone mass (7-9), with implications for the long-term musculoskeletal health of patients undergoing MBS. Given the role of fat-free mass in mobility, age-induced declines in physical function and strength may manifest early in individuals who have undergone MBS, potentially impacting activities of daily living. Systematic reviews and meta-analyses have shown a substantial decline in fat-free mass and lean mass in the first postoperative year (8, 9). Over this period, the rate of loss either plateaued or continued to decrease minimally, the latter could be associated with aging (10, 11). The rate of fat-free mass changes also varied across types of surgery, with findings suggesting better preservation following RYGB than SG (10). However, none of these systematic reviews and meta-analyses included OAGB surgery, which might impact the rate of fat-free mass loss differently compared with other types of MBS. Furthermore, the aforementioned studies did not include UK data, considering that presurgery and postsurgery care may vary between healthcare settings, potentially impacting postsurgery outcomes.

In terms of bone mineral density (BMD), patients undergoing MBS experience enduring increases in bone turnover markers (12, 13), significant declines in BMD at clinically relevant sites (ie, total hip, femoral neck, and lumbar spine) at 6 to 24 months postsurgery (12, 14, 15), and deteriorations in bone microstructure and estimated bone strength (15, 16), which are reflected in an overall increase in fracture risk (17-19). The importance of fat-free mass loss in relation to muscle strength and physical function, especially during the rapid weight loss period following MBS, remains poorly understood. Several studies have noted decreases in absolute muscle strength postsurgery, a key factor influencing physical function (20-22). However, a recent review suggested that physical function tends to improve after MBS, but it is unclear whether these improvements are due to direct alterations in body composition postsurgery or indirect changes in physical activity or other factors (23). Notably, the existing literature is hampered by inconsistent methodologies, including the evaluation of physical function, short follow-ups, and often small sample sizes (23).

To better inform clinical decisions, patients and clinicians need to understand the distinct effects of different types of MBS on health outcomes including body composition and musculoskeletal health. With regards to bone health, it is currently challenging to draw conclusions, as the available studies comparing the effects of RYGB and SG on BMD by dual energy x-ray absorptiometry (DXA) yielded contradictory results (24-30). While some of them propose that BMD loss might be more pronounced after RYGB than SG (24, 26, 27, 30), some others indicate similar reductions in BMD after both surgeries (25, 31). Improvements in physical function have been reported after both RYGB and SG; nevertheless, there are limited comparative data on whether the type of surgery differentially affects muscle strength and physical function (22, 32). Notably, very few studies have assessed the impact of OAGB on outcomes of musculoskeletal health, particularly in comparison to other types of surgery (33-35).

As such, the aim of the present study was to compare changes in body composition, BMD, muscle strength, and physical function in the first year following OAGB, RYGB, and SG within a UK-based healthcare setting.

Materials and Methods

This is a secondary outcome analysis of data collected from the BARI-LIFESTYLE randomized controlled trial (RCT), which primarily assessed the efficacy of a postsurgery lifestyle intervention program to maximize weight loss outcomes (36). The study was approved by the London–Dulwich Research Ethics Committee (17/LO/0950) and was conducted by the Centre for Obesity Research, University College London.

Participants

The eligibility criteria included adults aged 18-65 years scheduled to undergo either primary OAGB, RYGB, or SG and who met the National Institute for Health and Care Excellence eligibility criteria (37). Patients were deemed ineligible if they had a body weight of 200 kg or more due to DXA scan limitations, were nonambulatory, or had functional limitation. All participants provided written informed consent before participating. The detailed study rationale, recruitment, procedures, outcome measures, and planned data analysis of the RCT and observational cohort have been previously published (36, 38). Considering that the intervention program showed no significant impact on the primary and secondary outcomes of the main RCT (36), we decided to include all the participants in this analysis to increase our sample size. As such, our analysis included a total of 119 participants who underwent a repeat DXA scan at 12 months postsurgery. Among all participants, 16% of them underwent OAGB, 33% had RYGB, and 51% had SG.

Surgical Procedures

In all 3 study centers, the decision for type of surgery is based on informed patient preference after standardized counselling. This involves presenting the details, potential risks, and benefits of each type of surgery, adhering to the current international surgical recommendations for obesity and weight-related diseases (39). All types of surgery (OAGB, RYGB, and SG) were performed using a standard laparoscopic technique (40, 41). For OAGB, a lesser curvature-based stomach was created, and an anastomosis was constructed between the new stomach pouch and the jejunum, approximately 180 to 220 cm from the ligament of Treitz. For RYGB, a 30- to 40-mL gastric pouch was fashioned, and the alimentary limb was measured at 120 cm. The omentum was divided longitudinally, and a stapled jejuno-jejunal anastomosis was performed. In the case of SG, a sleeve was created around the bougie using a laparoscopic stapler, with a 2.0 mm staple height on the gastric antrum and body, and a 1.8 mm staple height for the rest of the stomach, along with staple line reinforcement.

Postsurgery Follow-up Care

All participants received standardized postoperative MBS care as stipulated by the National Institute for Health and Care Excellence (37). This care involved regular monitoring of dietary intake, vitamin and mineral deficiencies, comorbidities, and medication reviews by their respective MBS centers. Additionally, participants received verbal advice on physical activity and nutrition based on the guidelines from the British Obesity and Metabolic Surgery Society (42) and in accordance with local follow-up pathways. In addition to the standard care, participants in the intervention group also received 15 minutes of nutritional behavioral tele-counselling totaling 17 sessions that were spread throughout the first year of surgery plus a once weekly supervised exercise program commenced at 3 months postsurgery for 12 weeks (36, 43).

Outcome Measures

Total body weight, body composition including visceral adipose tissue (VAT), and BMD, alongside BMD at clinically relevant sites (total hip, femoral neck, and lumbar spine) were assessed by DXA (Discovery A DXA system, software V.13.4.2; Hologic; Marlborough, MA). %WL was calculated using the following formula: %WL = [(presurgery weight − weight at 12 months postsurgery)/presurgery weight] × 100. Appendicular lean mass was calculated as the sum of lean mass of the arms and legs. The static muscle strength of the upper extremities was measured using the handgrip strength test (Jamar Hydraulic Hand Dynamometer, Patterson Medical). Absolute handgrip strength was calculated as the greatest value of the average of 3 measurements of either the dominant or nondominant hand (44). The recent consensus by the European Society for Clinical Nutrition and Metabolism and the European Association for the Study of Obesity recommends the necessity to adjust handgrip strength to body mass. This is in view of sarcopenia may affect individuals with obesity at any age (45). Therefore, 2 indices of relative handgrip strength were also calculated by dividing absolute handgrip strength by body weight or appendicular lean mass (handgrip strength/aLM) (21). Physical function was assessed with the sit to stand (STS) test (46) and the 6-minute walking test (6MWT) (47).

Covariates

Height was determined using a stadiometer (Seca 242, Seca, Hamburg, Germany) to the nearest 0.01 meter. Body mass index (BMI) was calculated by dividing the body weight (kg) by the height squared (m^2). Participants self-reported the use of calcium/vitamin D supplements, diabetes medications, menopausal status, hormone replacement therapy (HRT) and smoking habit at baseline and at 3 and 12 months postsurgery. All patients were advised to stop smoking prior to undergoing MBS.

Statistical Analysis

Continuous data are presented as mean and SD. Categorical data are presented as counts and percentages. Differences in the baseline characteristics between the 3 types of surgery were analyzed using Kruskal–Wallis for continuous variables and the χ^2 test for categorical variables. Paired samples t-tests were performed to detect differences between presurgery and postsurgery within each type of surgery. Univariate and multivariate regression models were used to assess the effects of types of surgery on body weight, body composition, VAT, BMD, muscle strength, and physical function. Multivariate regression models were adjusted for age, sex and menopausal status, height, weight, ethnicity, trial arm (group allocation of the main RCT), and surgery site. For bone health outcomes, models were further adjusted for smoking status, calcium and/or vitamin D supplements, HRT use, BMD at baseline, and %WL. As sensitivity analysis, a 2-way analysis of variance was performed to explore the main effects of surgery type and trial arm, as well as their interaction on the reported outcomes. $P \leq .05$ was considered to be a statistically significant difference. Data analyses were performed using Stata 17 (StataCorp, College Station, TX).

Results

This analysis included 119 adults (77% women) with a mean age of 45.9 ± SD 10.3 years and a mean BMI of 43.6 ± 5.5 kg/m^2 (Table 1). Age, BMI, sex, menopausal status, ethnicity, socioeconomic, and smoking status at baseline were not significantly different by type of surgery. The majority of OAGBs (63%) were performed at the Whittington Hospital, while most RYGBs (46%) took place at the Homerton Hospital and the majority of SGs (71%) were undertaken at UCLH (P for surgery site < .001). This pattern reflects real-world clinical scenarios at the respective surgery sites. There was a trend toward a less frequent use of diabetes medications at baseline among those who underwent SG compared with those who had OAGB and RYGB (OAGB 37%, RYGB 39%, SG 18%, $P = .053$).

Baseline body weight and body composition did not significantly differ by surgery type. Total body aBMD and aBMD at the total hip, femoral neck, and lumbar spine at baseline did not differ between types of surgery (Table 1). Mean aBMD T-scores at the total hip, femoral neck, and lumbar spine were 0.5 to 1.6. None of the participants had osteoporosis (BMD T-score at the total hip, femoral neck, or lumbar spine ≤−2.5), while 28 participants (24% of the total cohort, OAGB n = 5 or 26%, RYGB n = 12 or 31%, SG n = 11 or 18%) had osteopenia (BMD T-score between −1 and −2.5), with no between-surgery differences. Fifteen percent of the patients reported taking calcium and/or vitamin D supplements at baseline, with none of the OAGB patients using these supplements ($P = .11$). Handgrip strength and physical function test scores did not differ between types of surgery at baseline (Table 1).

Weight Loss and Changes in Body Composition

The changes in body weight and body composition, within and between surgery types, are shown in Fig. 1 (also Fig. S1 (48)). At 12 months postsurgery, patients experienced significant weight loss following all procedures (OAGB −26.7 ± 8.4%, RYGB −26.9 ± 7.3%, SG −25.1 ± 9.1%, all $P < .001$). These reductions in body weight resulted in significant losses of both fat mass (OAGB −38.5 ± 14.3%, RYGB −37.6 ± 13.3%, SG −34.9 ± 16.5%, all $P < .001$) and lean

Table 1. Baseline characteristics of the participants

	Total (n = 119)	OAGB (n = 19)	RYGB (n = 39)	SG (n = 61)	*P* value
Age	45.9 ± 10.3	45.9 ± 10.9	44.8 ± 10.1	46.6 ± 10.3	.74
Height (m)	1.67 ± 0.08	1.66 ± 0.07	1.68 ± 0.09	1.67 ± 0.09	.61
Weight (kg)	121.7 ± 17.8	123.7 ± 20.2	118.5 ± 16.1	123.2 ± 18.2	.48
BMI (kg/m^2)	43.6 ± 5.5	44.8 ± 6.5	41.9 ± 5.0	44.4 ± 5.4	.07
Women, n (%)	92 (77.3)	14 (73.7)	31 (79.5)	47 (77.1)	.88
Premenopausal, n (%)	66 (71.7)	11 (78.6)	24 (77.4)	31 (66.0)	.45
Ethnicity, n (%)					
White	66 (55.5)	7 (36.8)	19 (48.7)	40 (65.6)	.21
Mixed race	5 (4.2)	2 (10.5)	1 (2.6)	2 (3.3)	
Asian or Asian British	11 (9.2)	2 (10.5)	6 (15.4)	3 (4.9)	
Black or Black British	29 (24.4)	5 (26.3)	11 (28.2)	13 (21.3)	
Chinese or other ethnicity	8 (6.7)	3 (15.8)	2 (5.1)	3 (4.9)	
Education level, n (%)					
No qualification	8 (6.7)	1 (5.3)	2 (5.1)	5 (8.2)	.66
GCSE/O level or equivalent	28 (23.5)	4 (21.0)	8 (20.5)	16 (26.2)	
A level or equivalent	26 (21.9)	3 (15.8)	7 (18.0)	16 (26.2)	
University degree	30 (25.2)	5 (26.3)	13 (33.3)	12 (19.7)	
Higher degree	21 (17.7)	6 (31.6)	7 (18.0)	8 (13.1)	
Others	6 (5.0)	0 (0)	2 (5.1)	4 (6.6)	
Employment status, n (%)					
Employed	87 (73.1)	13 (68.4)	26 (66.7)	48 (78.7)	.64
Unemployed	28 (23.5)	5 (26.3)	12 (30.8)	11 (18.0)	
Others	4 (3.4)	1 (5.3)	1 (2.5)	2 (3.3)	
Trial arm, n (%)					
Control	52 (43.7)	8 (42.1)	17 (43.6)	27 (44.3)	.99
Intervention	67 (56.3)	11 (57.9)	22 (56.4)	34 (55.7)	
Surgery site, n (%)					
UCLH	52 (43.7)	5 (26.3)	4 (10.3)	43 (70.5)	**<.001**
Whittington	34 (28.6)	13 (63.2)	17 (43.6)	5 (8.2)	
Homerton	33 (27.7)	2 (10.5)	18 (46.2)	13 (21.3)	
Smoking status, n (%)					
Never	1 (0.8)	0 (0)	0 (0)	1 (1.6)	.19
Past smokers	53 (44.5)	6 (31.6)	14 (35.9)	33 (54.1)	
Current smokers	65 (54.6)	13 (68.4)	25 (64.1)	27 (44.3)	
Calcium/vitamin D supplements, n (%)	18 (15.1)	0 (0)	8 (20.5)	10 (16.4)	.11
Diabetes medications, n (%)	33 (27.7)	7 (36.8)	15 (38.5)	11 (18.0)	.053
Body composition					
Total body lean mass (kg)	66.3 ± 10.4	67.8 ± 10.1	65.5 ± 10.6	66.3 ± 10.4	.75
aLM (kg)	29.4 ± 5.8	30.1 ± 5.5	29.4 ± 5.9	29.2 ± 5.8	.87
Total body fat mass (kg)	52.8 ± 12.2	53.2 ± 13.6	50.4 ± 10.1	54.30 ± 12.9	.38
Total body fat percentage (%)	43.2 ± 6.1	42.6 ± 5.8	42.5 ± 5.8	43.8 ± 6.4	.32
VAT mass (g)	812 ± 350	861 ± 350	741 ± 323	843 ± 357	.14
BMD					
Total hip BMD ($g·cm^{-2}$)	1.157 ± 0.130	1.152 ± 0.148	1.135 ± 0.112	1.173 ± 0.134	.47
Femoral neck BMD ($g·cm^{-2}$)	0.993 ± 0.759	0.934 ± 0.184	0.913 ± 0.144	0.928 ± 0.142	.88
Lumbar spine BMD ($g·cm^{-2}$)	1.146 ± 0.165	1.147 ± 0.185	1.126 ± 0.147	1.158 ± 0.171	.80
Total body BMD ($g·cm^{-2}$)	1.197 ± 0.106	1.191 ± 0.103	1.190 ± 0.103	1.203 ± 0.111	.91
Muscle strength and physical function					
Absolute handgrip strength (kg)	34.9 ± 8.5	35.8 ± 8.0	34.4 ± 8.1	35.0 ± 9.0	.92
Handgrip strength/body weight	0.29 ± 0.07	0.29 ± 0.06	0.30 ± 0.09	0.30 ± 0.06	.91
Handgrip strength/aLM	1.22 ± 0.25 .2530777	1.25 ± 0.30	1.19 ± 0.24	1.22 ± 0.25	.65

(*continued*)

Table 1. Continued

	Total (n = 119)	OAGB (n = 19)	RYGB (n = 39)	SG (n = 61)	*P* value
Sit to stand test (seconds)	11.0 ± 5.0	12.2 ± 9.0	10.8 ± 2.8	10.7 ± 4.3	.56
6-minute walking test (m)	419 ± 64	412 ± 91	421 ± 53	419 ± 61	.84

Bold value indicates a statistically significant difference.
Abbreviations: aLM, appendicular lean mass; BMD, bone mineral density; BMI, body mass index; GCSE, General Certificate of Secondary Education; OAGB, one-anastomosis gastric bypass; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; UCLH, University College London Hospitals; VAT, visceral adipose tissue.

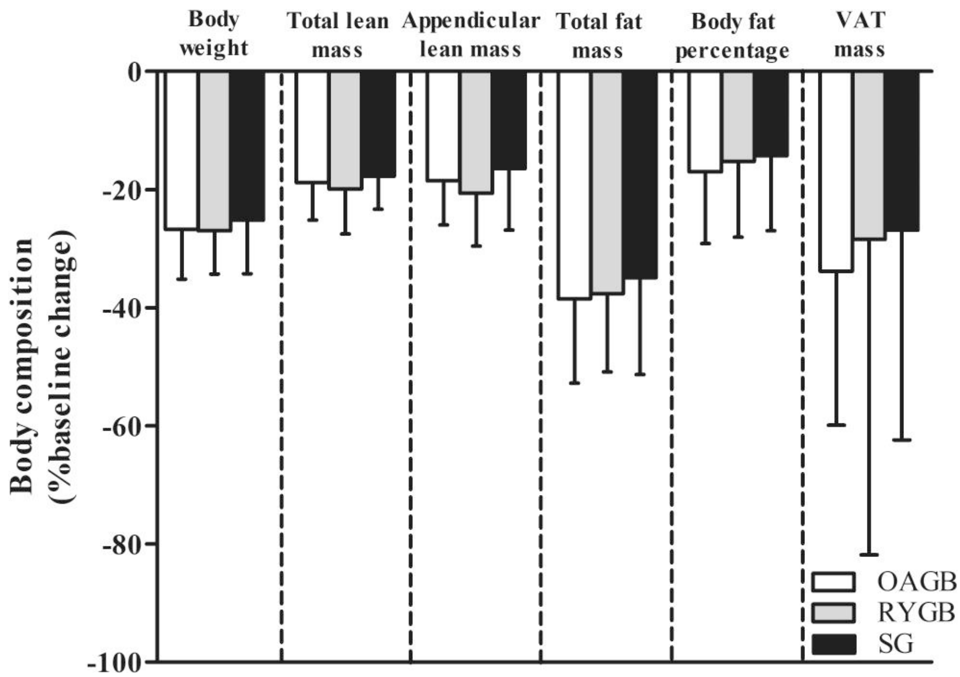

Figure 1. Changes (% from baseline) in body weight and body composition at 12 months after one-anastomosis gastric bypass (OAGB), Roux-en-Y gastric bypass (RYGB), and sleeve gastrectomy (SG). Bars and whiskers indicate mean ± SD. VAT, visceral adipose tissue.

mass (OAGB −18.9 ± 6.3%, RYGB −19.9 ± 7.6%, SG −17.7 ± 5.6%, all *P*- < .001). Body fat percentage (OAGB −17.0 ± 12.2%, RYGB −15.2 ± 12.8%, SG −14.2 ± 12.7%, all *P*- < .001), and VAT mass (OAGB −33.8 ± 26.1%, RYGB −28.4 ± 53.4%, SG −26.8 ± 35.6%, all *P* < .001) reduced significantly within all surgery types. Changes in body weight and body composition did not differ by type of surgery in univariate (Fig. 1) or multivariate models. In a sensitivity analysis, we found no main effects of trial arm or interactions between surgery type and trial arm for body weight or body composition, apart from a significant surgery type–trial arm interaction for VAT where participants in the control group who underwent RYGB had lower VAT loss than those in the control group who underwent the same type of surgery (Table S1 (48)).

Changes in Bone Mineral Density

The changes in BMD, within and between surgery types, are shown in Fig. 2 (also Fig. S2 (48)). There were significant reductions in total hip (OAGB −9.6 ± 4.0%, RYGB −9.8 ± 3.9%, SG −6.5 ± 3.7%, all *P* < .001), femoral neck (OAGB −7.8 ± 9.2%, *P* = .002, RYGB −6.7 ± 6.1%, *P* < .001, SG −3.3 ± 7.3%, *P* < .001), and lumbar spine aBMD (OAGB −4.4 ± 4.9%, *P* = .002, RYGB −4.5 ± 4.5%, *P* < .001, SG −2.0 ± 3.2%, *P* < .001) at 12 months after all types of surgery. The reductions in aBMD at these sites were significantly greater after OAGB (all *P* ≤ .02) and RYGB (all *P* ≤ .03) than after SG, while there were no significant differences between RYGB and OAGB (Fig. 2). Overall, these results remained significant after adjustments for age, sex, menopausal status, height, weight, smoking status, ethnicity, calcium and/or vitamin D supplements, HRT use, trial arm, surgery site, BMD at baseline, and %WL after surgery with the exception of the following comparisons which did not persist (femoral neck RYGB vs SG, *P* = .09; lumbar spine OAGB vs SG, *P* = .08, Fig. S3 (48)). Total body BMD remained unchanged from baseline in the OAGB (−0.2 ± 3.1%) and RYGB (0.0 ± 3.7%) but increased in patients who underwent SG (1.4 ± 2.5%, *P* < .001). These changes seen after SG were significantly different from those observed after OAGB and RYGB in unadjusted and adjusted analyses (all *P* < .05) (Fig. 2; Fig. S3 (48)). After surgery, 1 participant had osteoporosis (BMD T-score at the total hip, femoral neck, or lumbar spine ≤−2.5) while 29 participants (24% of the total cohort) had osteopenia (BMD T-score between −1 and −2.5). In total, 8 participants (7% of the total cohort) experienced worsening of their BMD status postsurgery. Specifically, in the OAGB group, 3 participants (16%) with normal BMD T-score at baseline had BMD T-score indicating

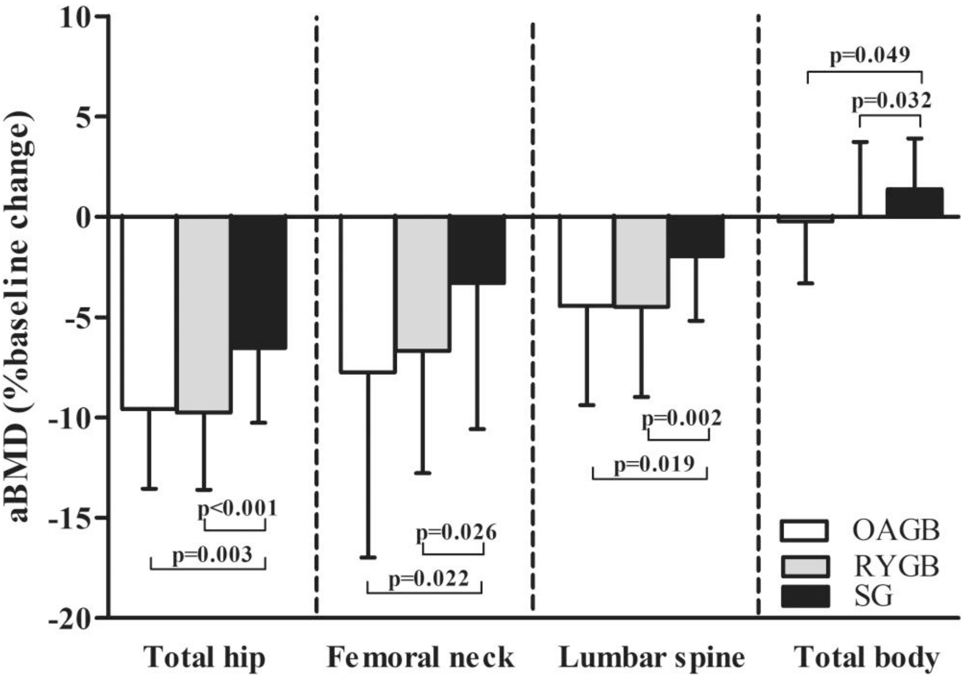

Figure 2. Changes (% from baseline) in aBMD at 12 months after one-anastomosis gastric bypass (OAGB), Roux-en-Y gastric bypass (RYGB), and sleeve gastrectomy (SG). Bars and whiskers indicate mean ± SD. aBMD, areal bone mineral density.

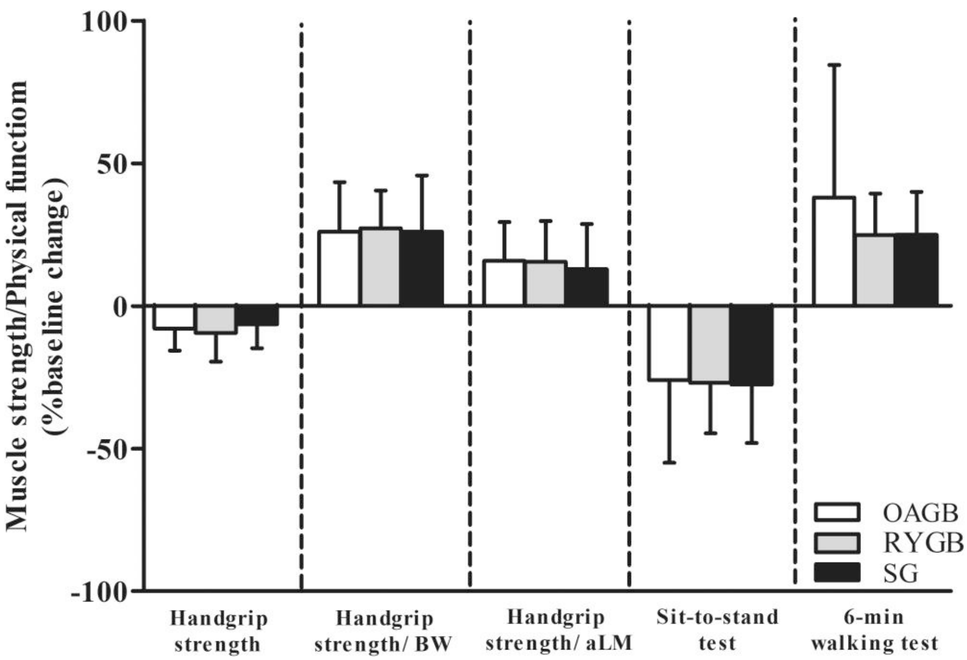

Figure 3. Changes (% from baseline) in absolute and relative handgrip strength and physical function tests at 12 months after one-anastomosis gastric bypass (OAGB), Roux-en-Y gastric bypass (RYGB), and sleeve gastrectomy (SG). Bars and whiskers indicate mean ± SD. aLM, appendicular lean mass; BW, body weight.

osteopenia at 1 year postsurgery, and 1 participant (5%) with osteopenia at baseline had BMD T-score in the osteoporotic range after surgery. In the RYGB group, 1 participant (3%) with normal BMD status at baseline had BMD T-score indicating osteopenia after surgery. In the SG group, 3 participants (5%) with normal BMD status at baseline had BMD T-score indicating osteopenia postsurgery. In a sensitivity analysis, there was neither a main effect of trial arm nor a surgery type–trial arm interaction for any BMD outcomes (Table S1 (48)).

Changes in Muscle Strength and Physical Function

The changes in muscle strength and physical function, within and between surgery types, are shown in Fig. 3 (also Fig. S4 (48)). Absolute handgrip strength decreased significantly at

12 months postsurgery relative to presurgery values within all types of surgery (OAGB −7.9 ± 7.8%, RYGB −9.4 ± 10.1%, SG −6.4 ± 8.4%, all $P < .001$). In contrast, relative muscle strength (handgrip strength/body weight—OAGB 26.0 ± 17.4%, RYGB 27.1 ± 13.2%, SG 15.8 ± 13.6%, all $P < .001$; and handgrip strength/aLM—OAGB 26.0 ± 17.4%, RYGB 15.4 ± 14.3%, SG 12.8 ± 15.9%, all $P < .001$) increased significantly at 12 months in all types of surgery. There were no differences in handgrip strength expressed in absolute or relative changes by types of surgery (Fig. 3).

The time taken to perform the STS test (OAGB −25.9 ± 29.0%, $P = .021$; RYGB −26.9 ± 17.8%, $P < .001$; SG −27.4 ± 20.6%, $P < .001$) and the distance covered during the 6MWT (OAGB 38.0 ± 46.5%, RYGB 24.8 ± 14.6%, SG 25.0 ± 15.0%, all $P < .001$) improved significantly at 12 months within all types of surgery, with no between-surgery differences in univariate (Fig. 3) or multivariate models. In a sensitivity analysis, we found no main effects of trial arm or surgery type–trial arm interaction for any parameters of muscle strength or physical function (Table S1 (48)).

Discussion

In this secondary data analysis of the BARI-LIFESTYLE trial, OAGB, RYGB, and SG were effective in reducing body weight and body fat, though also resulted in loss of lean mass, with no difference between types of surgery. Despite reductions in lean mass and absolute handgrip strength, improvements in relative handgrip strength and physical function were observed after all types of surgery, with no significant differences between surgical types. In terms of bone health, all types of surgery were associated with reductions in BMD at the total hip, femoral neck, and lumbar spine, though not at the total body. Notably, OAGB and RYGB resulted in more pronounced decreases in BMD at these sites compared with SG, while there were no significant differences between the 2 types of gastric bypass.

To date, only a few RCTs have evaluated the extent of weight loss following OAGB compared with RYGB and SG (49-51). In 2 RCTs involving patients undergoing OAGB vs RYGB, comparable weight loss was reported in the first year after surgery (33, 52). In another RCT comparing OAGB and SG, weight loss of similar magnitude was observed at 1 year postsurgery. Our results align with findings from these RCTs and data from the UK National Bariatric Surgery Registry (6), demonstrating comparable short-term (1 year) weight loss following OAGB vs RYGB and SG.

Multiple studies have concluded that there are similar changes in body composition between RYGB and SG at 1 year postsurgery (53, 54). However, very limited comparative studies currently exist for OAGB (33-35). Based on the only RCT currently available, there were no differences in body composition changes between OAGB and RYGB at 1 year postsurgery (33), which is consistent with our findings. Two longitudinal studies comparing body composition by bioelectrical impedance between OAGB and SG have shown conflicting results (34, 35). While Pakzad et al showed no difference in body composition changes between the 2 types of surgery (35), data from the Tehran Obesity Treatment Study demonstrated better fat-free mass preservation and a greater loss of fat mass following OAGB than SG (34). These discrepancies may be explained by differences in the study populations and follow-up periods of the 2 studies (ie, 1 year vs 3 years) (34, 35) and highlight the need for additional studies, especially RCTs, with robust study designs, before a definitive conclusion can be made.

In the present cohort, patients experienced significant BMD reductions at the level of the hip (total hip, femoral neck) and lumbar spine. Only 1 previous study has assessed BMD changes by DXA following OAGB (n = 50), demonstrating significant decreases in total hip (−13%), lumbar spine (−7%), and total body (−1%) BMD at 12 months postsurgery (55). We observed BMD decreases of smaller magnitude at the total hip and lumbar spine and maintenance of total body BMD at 1 year following OAGB. Importantly, our study is the first to report that these BMD changes were more pronounced than those after SG but did not differ from those seen after RYGB. Our work further contributes to the growing literature comparing BMD changes after RYGB and SG (24-30). In line with our findings, 2 RCTs reported greater BMD reductions at the total hip (26), femoral neck (26), and lumbar spine BMD (26, 30) following RYGB than SG (26). Some other nonrandomized studies have also shown more substantial BMD decreases at the total hip (24, 27) and femoral neck (24) but not at the lumbar spine after RYGB compared with SG. In contrast, in other nonrandomized studies, patients who underwent RYGB and SG experienced BMD reductions at different clinical sites postsurgery, with no significant differences observed between the 2 types of surgery (25, 31). These conflicting results may be related to differences in study design (randomized vs nonrandomized, small sample sizes), characteristics of the study populations (eg, age, sex, menopausal status, baseline BMI, presence of comorbidities such as type 2 diabetes) as well as patients' compliance with the postsurgery lifestyle advice.

Several underlying mechanisms have been proposed to explain bone loss after MBS. These include decreases in skeletal loading with weight loss, loss of muscle mass, changes in endocrine factors (adipokines, sex steroids, and gut-derived hormones), alterations in bone marrow adiposity, as well as nutrient malabsorption (due to anatomical rearrangements of the gastrointestinal tract) and nutrition deficiencies (due to poor postsurgery dietary intakes) (13, 56). In the present study, there were no differences in weight loss and changes in body composition between the different types of surgery, suggesting that other factors may account for the observed BMD differences following different procedures. We hypothesize that differences in the anatomical modifications of the gastrointestinal tract as part of the gastric bypasses and SG resulting in greater malabsorption of micronutrients (notably calcium and vitamin D) in the former procedures may contribute to the different BMD responses postsurgery (57). Whereas the observed relative preservation of total body BMD (compared with the fracture-prone hip and spine) following MBS in this study may be attributed to its combination of bone density measurements from multiple skeletal sites, which include those less prone to the impact of weight loss or hormonal changes. Future studies are needed to provide additional mechanistic insights of bone loss after the different types of MBS.

Finally, our study provides novel data into changes in muscle strength and physical function after OAGB, RYGB, and SG. When expressed in absolute terms, we showed that compared with baseline values, handgrip strength significantly decreased at 12 months after all types of surgery. The results align with previous studies indicating a decline in absolute upper and lower body muscle strength postsurgery (20-22), but contrast with a recent systematic review demonstrating that absolute handgrip strength was unaffected by MBS (58). Considering the significant weight loss postsurgery experienced by patients in all types of surgery, we further evaluated changes in relative muscle strength by dividing handgrip strength by body weight and aLM, a method employed previously to assess "muscle quality" (21). Notably, there were significant increases in relative strength 12 months postsurgery, consistent with previous work (21). There were no differences in handgrip strength changes between OAGB, RYGB, and SG, which could be explained by the similar extent of weight loss and body composition changes across all types of surgery. Taken together, our findings suggest that the improvements in relative muscle strength are distinct from the decreases in lean mass in the context of MBS.

Our results further support a discrepancy between lean mass and physical function changes after MBS. Indeed, consistent with previous studies (21, 59), we also observed a mean improvement between −2 to −4 seconds in the STS test assessed in the first postoperative year. The changes, although significant, are below the minimal clinically important difference (MCID) of −5 to −7 seconds, a range developed based on patients with chronic musculoskeletal pain (60). One factor that may explain the below the MCID range in the present study is that patients with functional limitations and nonambulatory patients were excluded during screening. Therefore, patients in the current cohort were not considered to have severe musculoskeletal issues prior to surgery and were fairly fit when they performed the test presurgery. We also observed improvements in the 6MWT which are in line with previous studies that reported improvement ranging from 85 to 150 meters at 12 months postsurgery (61, 62). The mean distance change in our cohort tripled the MCID of 14.0 to 30.5 meters (63), indirectly translating to improved cardiorespiratory fitness of participants following MBS.

In recent years, glucagon-like peptide-1 receptor agonists (GLP-1RAs) have been shown to promote significant weight loss in adults with overweight and obesity (64, 65). Similar to MBS, GLP-1RAs lead to a substantial decrease in fat mass, but their impact on lean mass still remains unclear. Data from the STEP 1 and SURMOUNT-1 trials suggest that lean mass loss seems to occur to a lesser extent than in our cohort (64, 65). Whereas the impact of GLP-1RAs on BMD remains unknown due to limited clinical data currently existing in adults with overweight and obesity (66). Studies directly comparing MBS and GLP-1RAs on body composition, including BMD, are now warranted.

Strengths and limitations

To our knowledge, these are the first UK data reporting outcomes of MBS on body composition and BMD. Our findings contribute to the paucity of evidence regarding the impact of OAGB on health outcomes, especially compared with other types of surgery (ie, RYGB and SG). Body composition and BMD were assessed by DXA, which is the reference gold standard (67), and validated tests were used to assess muscle strength and physical function.

This study is not without limitations. The unequal sample sizes representing each type of surgery have limited the interpretation of our results. However, this imbalance reflects the real-world scenario of the chosen types of MBS undertaken in the UK and globally between 2018 and 2019 (the recruitment period of this study) (2, 6). Specifically, for OAGB, only 4% and 6.6% of this procedure was performed in the UK and worldwide, respectively (2, 6). This is a secondary data analysis, which is not powered to detect significant differences between operations and participants were not randomized to the surgical types. Despite the absence of major differences in baseline characteristics between surgical types, these may not be fully comparable, which might have influenced some between-surgery comparisons over the follow-up period. To alleviate this discrepancy, we adjusted our analyses for a number of different confounders. Hence, RCTs with larger sample sizes and equal distributions between all 3 types of surgery are needed to gain a better understanding on the influence of surgical types on health outcomes. Another limitation is the present study comprised a substantial proportion of women (77%), a demographic characteristic frequently observed in patients undergoing MBS. Additionally, 56% of participants in the original study received an adjunctive lifestyle intervention program, which may have influenced the reported outcomes. Although overall, in our sensitivity analyses, we did not find significant main effects of trial arm or interactions between trial arm and surgery types on the reported outcomes (with the exception of VAT), the results of the present analysis should be interpreted with this context in mind. Lastly, the absence of data on serum bone-related markers such as calcium, phosphate, parathyroid hormone, and 25-hydroxyvitamin D, along with dietary data, limits the interpretations of our results.

Conclusion

In conclusion, MBS (OAGB, RYGB, and SG) delivered in a UK healthcare setting produced substantial weight loss alongside improvements in body composition, relative muscle strength, and physical function. Nevertheless, it was accompanied by loss of lean mass, upper body muscle strength (in absolute terms), and BMD. Changes in body weight, body composition, and physical function were not different between the 3 types of surgery. However, OAGB and RYGB were associated with more pronounced reductions in BMD at clinically relevant sites compared with SG. These results have implications for BMD monitoring and patients' management to maximize the benefits of MBS and limit undesirable consequences. Longer-term studies are warranted to explore differences in fracture risk after OAGB, RYGB, and SG.

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Author Contributions

F.C.J.: conceptualization; literature search; participant recruitment; data collection; data interpretation; writing—original draft. M.P.: conceptualization, literature search; data analysis; data interpretation; writing—original draft; figures. A.C.: conceptualization; project administration; supervision. H.K., J.D., A.K., N.L., and A.B.: delivering intervention; writing—review and editing. G.M., K.C., R.Z., and J.M.: participant recruitment; data collection; writing—review and editing. P.M.: data management; writing—review and editing. E.M., J.W., T.-H.C., and J.M.: writing—review and editing. K.D. and C.P.: principal investigator; writing—review and editing. R.L.B.: chief investigator; conceptualization; methodology; data curation; funding acquisition; resources; supervision; writing—review and editing. All authors approved the final version.

Disclosures

F.C.J., M.P., E.M., A.C., H.K., J.D., A.K., N.L., G.M., P.M., K.C., J.M., J.W., T.-H.C., K.D., and C.P. have nothing to declare. R.L.B. reports receiving consulting fees from Pfizer, Eli-Lilly, Gila Therapeutics Inc., and ViiV Healthcare and consulting fees, lecture fees from Novo Nordisk and participating in clinical trials for Novo Nordisk. From May 2023, she is a full-time employee and shareholder for Eli-Lilly and Company Ltd, Basingstoke, UK. J.M. reports funding from the NIHR and institutional funding from Novo Nordisk and the Society for Endocrinology. R.Z. reports funding from the NIHR and Royal College of Surgeons of England. A.B. reports honoraria from Novo Nordisk, Office of Health Improvement and Disparity, Johnson and Johnson and Obesity UK outside the submitted work and is on the Medical Advisory Board and shareholder of Reset Health Clinics Ltd.

Data Availability

Some or all datasets generated during and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

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Clinical Trial Information

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