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The Reported Prevalence of Micronutrient Deficiency after Metabolic Bariatric Surgery and Adherence to British Obesity and Metabolic Specialist Society Nutritional Guidelines: A Multicentre Retrospective Cohort Study

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Abstract

Introduction Micronutrient deficiencies are common after metabolic bariatric surgery and can lead to serious health complications. The British Obesity and Metabolic Specialist Society recommend routine micronutrient monitoring and supplementation to prevent deficiency, yet real-world adherence to these recommendations is unknown, and multicentre data on postoperative micronutrient status is limited. This study assessed the prevalence of micronutrient deficiencies and adherence to nutritional guidance during the first 12 months after metabolic bariatric surgery in the UK.

Methods A multicentre retrospective cohort study was conducted across 13 bariatric centres across England. Adults undergoing primary metabolic bariatric surgery in 2021 were included. Site-level data were collected on preoperative and 3-, 6- and 12-month postoperative micronutrient levels, clinician blood test requests, and patient-reported adherence to recommended supplementation. The prevalence of each micronutrient deficiency was calculated using patients with available data.

Results Data were available for 669 patients. Early postoperative blood monitoring was inconsistent, with a clinician requesting tests for 33.7% of patients at 3 months, 60.0% at 6 months, and 88.4% at 12 months. Amongst patients tested, low Vitamin D and folate levels were less prevalent at 12 months compared to preoperative values. Low zinc and selenium levels were observed amongst patients who underwent testing during the 12 month follow up period, with low zinc seen more frequently after sleeve gastrectomy than gastric bypass at all follow-up points – prevalence estimate (95% CI): 16.7% (5.8–39.2) vs. 11.5% (4.0–29.0) at 3 months; 27.6% (14.7–45.7) vs. 10.0% (4.0–23.1) at 6 months; 32.2% (23.2–42.6) vs. 26.0% (18.5–35.1) at 12 months. However, these findings should be interpreted cautiously given the limited availability of trace mineral data and the potential for selective testing. Where recorded, approximately two-thirds of patients self-reported full adherence to supplementation.

Conclusion Among patients with available biochemical testing, micronutrient deficiencies were frequently observed during the first year after MBS. The observed frequency of low zinc and selenium amongst tested patients warrants further prospective investigation to explore clinical implications and to evaluate the earlier and more systematic monitoring of trace minerals after MBS. Inconsistencies in micronutrient blood monitoring and substantial missing postoperative data may suggest that the BOMSS nutritional monitoring guidelines are not being fully implemented in clinical practice across England, limiting the availability of real-world postoperative micronutrient data.

Key points

- This study analysed data for 669 patients from 13 bariatric centres across England.
- Clinician adherence to blood monitoring as per BOMSS guidelines was lower at 3 and 6 months than at 12 months.
- In the patients tested, low levels of certain micronutrients were more common after sleeve gastrectomy than gastric bypass.
- Future studies should investigate whether earlier and more systematic monitoring of zinc and selenium after metabolic bariatric surgery is warranted.

Keywords Obesity · Bariatric surgery · Micronutrient deficiency · Guideline adherence

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Introduction

The effectiveness of metabolic bariatric surgery (MBS) in treating severe obesity and improving cardiometabolic health in people living with this chronic condition is well-established [1–3]. However, people who undergo MBS are at an increased risk of micronutrient deficiencies due to multiple factors, including changes in physiology, reduced nutrient exposure to the intestine, altered digestion, reduced dietary intake, maladaptive eating patterns, and alterations in gut bacteria [4, 5]. The most common micronutrients with low levels/deficiency after MBS include iron, vitamin D, calcium, vitamin B12 and folate which, if left unmonitored and without treatment, may lead to serious health consequences such as anaemia, osteoporosis and irreversible neurological damage [4, 6]. In addition, it is important to acknowledge that the presence of obesity alone is also a risk factor for micronutrient deficiency, and it is likely that individuals undergoing metabolic bariatric surgery will have at least one deficiency preoperatively [7–9].

Globally, 543,000 primary MBS procedures were performed between 2023 and 2024. Sleeve gastrectomy is the most common MBS operation, accounting for 57% of cases, followed by 32% for Roux-en-Y gastric bypass and 6% for one anastomosis gastric bypass [10]. In the UK, between 6000 and 7000 MBS procedures are performed each year, with Roux-en-Y gastric bypass being the most common procedure (49%), followed by sleeve gastrectomy (35%), adjustable gastric band (11.5%), and one anastomosis gastric bypass (4%). The remaining MBS procedures, such as biliopancreatic diversion with duodenal switch, have reduced significantly in recent years in the UK and account for < 1% of procedures performed annually [11].

In 2020, The British Obesity and Metabolic Specialist Society (BOMSS) published an update to their guidelines for the pre- and post-operative nutritional management of MBS in the UK [12]. This consisted of graded recommendations based upon a systematic review of the available evidence alongside expert consensus. This guidance recommends procedure-specific lifelong postoperative micronutrient replacement, as well as the monitoring of bloods preoperatively and postoperatively. These guidelines are intended to be utilised by healthcare professionals involved in preparation and aftercare of people undergoing MBS in the United Kingdom.

Given the paucity of literature on the adherence to national guidance within MBS centres across England, and the lack of multicentre data on postoperative micronutrient deficiencies nationally, we conducted a collaborative multicentre study to investigate this further.

The primary aim of this study was to investigate the point prevalence of micronutrient deficiencies preoperatively and

at 3-, 6-, and 12-months postoperatively amongst adults undergoing MBS in the UK. Secondary objectives included (i) Exploring the overall presence of prevalence of micronutrient deficiency across MBS procedures, (ii) determining clinician adherence to requesting BOMSS (2020) recommended blood tests and (iii) determining reported patient adherence to BOMSS recommended micronutrient supplementation.

Methods

A multicentre retrospective cohort study was undertaken to investigate micronutrient deficiency after MBS, in addition to patient and clinician adherence to BOMSS nutritional guidelines [12]. Centres performing MBS within the UK (NHS or privately funded) were invited to contribute data for this study. NHS funded MBS surgery in the UK requires an individual to engage in a preoperative specialist obesity program with support from a specialist multidisciplinary team (MDT) and have a starting BMI ≥ 40 kg/m² or between 35 and 40 kg/m² with an obesity-related condition [13]. As per the guidance of the National Institute of Health and Care Excellence (NICE), individuals referred for MBS in the UK should have a BMI of 40 kg/m² or more, or between 35 and 39.9 kg/m² with the presence of an obesity-associated significant health condition (this BMI threshold can be reduced by 2.5 kg/m² for people with Asian, Middle Eastern, Black African or African–Caribbean ethnicity) [13].

Centre participation was advertised on a closed Google group forum for UK registered bariatric dietitians, at online regional bariatric dietitian network meetings, via the British Dietetic Association Obesity Specialist Group newsletter and via X (San Francisco, USA) social media platform.

Study Population

Adults (≥ 18 years of age) having undergone a primary MBS procedure between January 1st and December 31st 2021 were eligible for inclusion as this was the first complete 12 months following the update to BOMSS guidance [12]. Eligible procedures included adjustable gastric band (AGB), sleeve gastrectomy (SG), Roux-en-Y gastric Bypass (RYGB), one-anastomosis gastric bypass (OAGB), and biliopancreatic diversion with duodenal switch (BPD/DS), as BOMSS nutritional guidelines provide recommendations for these procedures [12]. The guidance advises that the nutritional monitoring after OAGB procedures is approached as per the RYGB procedure, providing the biliopancreatic intestinal limb length is ≤ 150 cm.

Data Collection

Data were collected and anonymised at the site level from existing patient records and included age at time of surgery, sex, ethnicity, weight (kg), BMI (kg/m^2), diagnosis of obesity-associated condition (type 2 diabetes, metabolic dysfunction-associated steatotic liver disease, chronic kidney disease, dyslipidaemia), procedure type, intestinal limb length (for OAGB/RYGB). Data on adherence to blood monitoring and reported patient adherence to micronutrient supplementation were collected at the preoperative and 3-, 6- and 12-month postoperative stages, as these are the timepoints recommended for routine blood monitoring in BOMSS 2020 guidelines [12]. Representatives from each MBS centre were assigned as data collectors following training from a member of the study team. Data collectors were asked to report whether a blood test had been requested by a clinician, with a response of ‘yes’ or ‘no’. Individual biochemical and haematological results were then reported as being either ‘in-range or above’ or ‘deficient/low’ according to the local laboratory reference ranges used by each centre. Blood test results for albumin, vitamin D, albumin-adjusted calcium, parathyroid hormone, folate, vitamin B12, ferritin (iron storage), haemoglobin (indicator for anaemia), zinc, copper and selenium were collected. If a data point was unavailable, this was recorded as ‘unknown’. Patient adherence to the BOMSS recommended oral micronutrient supplementation [12] was recorded as either ‘yes’, meaning the patient was taking all recommended supplements consistently at the correct dosage, or ‘no’, meaning the patient was not taking at least one of the recommended supplements. We did not collect data on adherence for individual supplements. Data were also collected separately on whether the patient was having 12-weekly vitamin B12 injection therapy.

Centres were asked to record if the follow up appointment was conducted face-face, via telephone or via video call. Once anonymised, data were collected using a standardised Microsoft Excel data extraction template and sent from individual sites to the study team via a secure email address and in a password-protected format. Individual site data were amalgamated into a single, anonymised dataset for analysis.

Data Analysis

Given the retrospective nature of this routinely collected dataset, there was a substantial proportion of missing data across centres and a low prevalence of deficiency for several micronutrients. As such, analyses were primarily descriptive, with the use of basic inferential statistical tests where appropriate. Comparisons between procedures are descriptive and

unadjusted, with no consideration of potential confounding and selection bias. Predictive modelling was considered but not undertaken, as key assumptions regarding data completeness and event frequency were not met. Baseline categorical variables were presented as frequencies with percentages and differences in characteristics between MBS procedures were assessed using the chi-square test. P-values below 0.05 were considered as statistically significant. Baseline continuous variables were summarised using median (interquartile range; IQR) or mean (standard deviation; SD), depending on data distribution, and compared between groups using one-way analysis of variance (ANOVA) or the Kruskal–Wallis test, as appropriate. RYGB and OAGB were combined to create a ‘gastric bypass’ group for analysis as the BOMSS guidelines are the same for these procedures (OAGB procedures with a biliopancreatic limb of > 150 cm were excluded). The prevalence estimate for each micronutrient was calculated only among patients who attended appointments and had available micronutrient data at each time point. 95% confidence intervals for key prevalence estimates was calculated using the Wilson method to ensure accuracy with small sample sizes. Changes in micronutrient deficiency between the pre-operative and 12-month follow-up time points were assessed using McNemar’s test.

Ethical Approval

Ethical approval for this study was granted by XXX University Research Ethics Committee on 19th November 2025 (reference number: P190XXX). All data was anonymised at site level and stored in a password protected file. As this was a retrospective study of routinely collected data, informed consent was not required.

Results

Data Availability and Centre Characteristics

Thirteen MBS centres across England (NHS $n=12$, private sector $n=1$) participated in this study and provided data for 669 patients. All centres were located in England, with regional coverage across the South West (3 centres), South East (3 centres), West Midlands (3 centres), East Midlands (2 centres), Yorkshire and the Humber (3 centres) and the North East (1 centre). The number of records provided by centres varied, with one centre contributing as few as six records (centre 6) and another contributing 187 records (centre 13). Most centres provided preoperative baseline data. However, centre 13 did not report preoperative BMI for 85/187 patients. Across all centres, there was a high level of missing micronutrient data at both pre- and post-operative

time points, with the completeness of data reporting varying markedly by centre.

Baseline Characteristics

The mean age of patients was 45.9 years (SD 11.1 years) with the majority being female (79.8%, $n=534$) and White (82.2%, $n=550$). The median preoperative body weight and BMI were 126.0 kg (IQR 111.2 to 145.0) and 45.9 kg/m² (IQR 41.3 to 52.0), respectively. Type 2 diabetes, dyslipidaemia and metabolic dysfunction-associated steatotic liver disease (MASLD) was diagnosed in 30.8% ($n=206$), 21.7% ($n=144$) and 9.6% ($n=64$) of patients respectively. RYGB was the most common procedure (48.4%, $n=324$), followed by SG (40.4%, $n=270$), OAGB (10.0%, $n=67$) and gastric band (1.2%, $n=8$). The biliopancreatic limb length was 150 cm or less in 83.6% of OAGB cases ($n=56/67$), with no reports of a biliopancreatic limb length exceeding 200 cm. No BPD/DS cases were reported. Table 1 provides

Fig. 1 Patient follow up, blood test request rate and available micronutrient data at 3, 6 and 12 months postoperatively. PTH: *parathyroid hormone*

a breakdown of baseline participant characteristics against procedure type.

Follow Up Attendance and Clinician Adherence to Requesting Recommended Blood Tests

Figure 1 provides an overview of patient follow up, clinician blood test request rate and micronutrient data at the 3, 6 and 12 month follow up periods. Overall, patient attendance was 90.5% (398/440), 81.0% (477/589) and 83.2% (490/589) at the 3, 6 and 12 months postoperative follow up intervals respectively. However, this varied considerably by centre. For patients who attended follow up, virtual consultations (i.e. telephone/video) were conducted in 59.5% (237/398) of patients at the 3-month postoperative interval, 81.3% (388/477) at 6 months and 61.6% (302/490) at 12

Table 1 Baseline preoperative participant characteristics

Demographic	All procedures ($n=669$)	Sleeve gastrectomy ($n=270$)	Roux-en-Y Gastric Bypass ($n=324$)	One Anastomosis Gastric Bypass ($n=67$)	Adjustable Gastric Band ($n=8$)	<i>P</i> value	SMD (SG vs. bypass)
Age (years), mean (SD)†	45.9 (11.1)	45.1 (11.4)	46.9 (10.9)	44.1 (11.0)	46.0 (7.6)	0.119	0.12
Female, n (%)‡	534 (79.8)	218 (80.7)	267 (82.4)	44 (65.7)	5 (62.5)	0.010	0.03
Ethnicity, n (%)‡	550 (82.2)	217 (80.4)	270 (83.3)	58 (86.6)	5 (62.5)	0.972*	0.01
White	15 (2.2)	5 (1.9)	9 (2.8)	1 (1.5)	0 (0.0)		
Asian	10 (1.5)	5 (1.9)	5 (1.5)	0 (0.0)	0 (0.0)		
Black	45 (6.7)	17 (6.3)	20 (6.2)	7 (10.4)	1 (12.5)		
Other	49 (7.4)	26 (9.6)	20 (6.2)	1 (1.5)	2 (25)		
Unknown							
Anthropometry							
Weight (kg), median (IQR)§	126.0 (111.2–145.0)	126.5 (113.6–146.1)	125.4 (110.0–142.8)	126.0 (111.4–153.8)	123.5 (106.7–146.2)	0.313	0.09
BMI (kg/m ²), median (IQR)§	45.9 (41.3–52.0)	46.0 (41.3–52.0)	45.5 (41.6–51.9)	45.7 (40.4–52.1)	42.5 (36.6–48.8)	0.526	0.00
Co-morbidities							
T2DM, n (%)‡	206 (30.8)	79 (29.3)	114 (35.2)	10 (14.9)	3 (37.5)	0.010	0.05
Missing	2 (0.3)	1 (0.4)	1 (0.3)	0 (0.0)	0 (0.0)		
MASLD, n (%)‡	64 (9.6)	27 (10.0)	33 (10.2)	4 (6.0)	0 (0.0)	0.555	0.02
Missing	4 (0.6)	3 (1.1)	1 (0.3)	0 (0.0)	0 (0.0)		
CKD, n (%)‡	15 (2.2)	7 (2.6)	7 (2.2)	1 (1.5)	0 (0.0)	0.910	0.04
Missing	6 (0.0)	4 (1.5)	2 (0.6)	0 (0.0)	0 (0.0)		
Dyslipidaemia, n (%)‡	144 (21.5)	57 (21.1)	76 (23.5)	9 (13.4)	2 (25.0)	0.327	0.01
Missing	5 (0.7)	3 (1.1)	2 (0.6)	0 (0.0)	0 (0.0)		

SMD=standardised mean difference (Cohen's d) comparing sleeve gastrectomy with combined gastric bypass (RYGB+OAGB). Values >0.1 indicate potential imbalance. Ethnicity SMD calculated as White vs. non-White

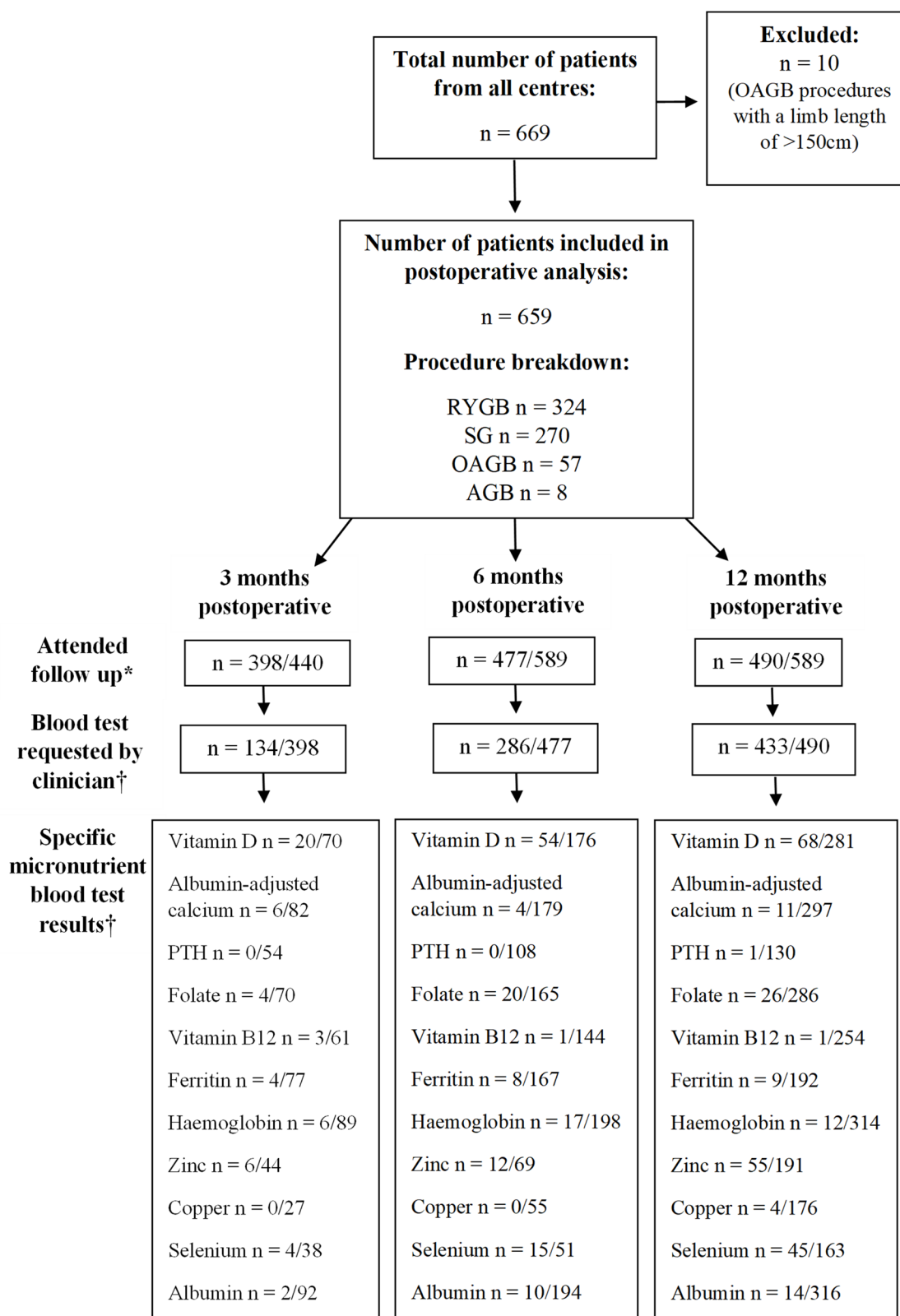
† Compared using one way ANOVA

‡ Compared using chi square test

§ Compared using Kruskal Wallis test

* White versus (Asian + Black + Other)

BMI: Body mass index; T2DM: type 2 diabetes mellitus; MASLD: metabolic dysfunction-associated steatotic liver disease; CKD: chronic kidney disease; IQR: interquartile range; SD: standard deviation



* Patients with reported data on attendance for each follow up period (yes/no)

† Patients that attended follow up and had available data for either clinician blood test requests or specific micronutrient data at each period

months. The remaining appointments were conducted in person.

For patients who attended follow up appointments, a postoperative blood test was requested by a clinician for 134/398 (33.7%) patients at 3 months, 286/477 (60.0%) at 6 months, and 433/490 (88.4%) at 12 months postoperatively.

Patient Adherence with Micronutrient Supplementation

Data were analysed on reported patient adherence to the recommended procedure-specific micronutrient supplementation as per the BOMSS guidance [12]. In patients who attended follow-up appointments and for whom supplementation adherence data were available, 61.5% ($n = 216/351$), 66.0% ($n = 282/427$) and 67.2% ($n = 301/448$) were reported as adhering to supplement recommendations at the 3, 6 and 12-month follow up intervals respectively. In those with available data, 86.2% ($n = 349/405$) and 91.1% ($n = 379/416$) of SG, RYGB and OAGB patients were receiving intramuscular vitamin B12 injections on a 12-weekly basis at the 6 and 12 month follow up intervals respectively.

Availability of Laboratory Results

Table 2 provides a breakdown of the reported pre and postoperative blood test parameters. A preoperative blood test was reported for 519 patients (77.6%). The reported individual BOMSS recommended preoperative micronutrient blood tests varied preoperatively, with folate being the most commonly tested (69.1%, $n = 462$), and ferritin being the least commonly tested (40.4%, $n = 270$).

OAGB procedures with a biliopancreatic limb length >150cm ($n = 11$) were excluded from the postoperative nutritional blood monitoring analysis due to low numbers and differences in BOMSS guidance for OAGB procedures with a biliopancreatic limb length of >150 cm. The

availability of data for each micronutrient level was lowest at the 3 month follow up interval and increased at the 6- and 12-month intervals. Although copper, selenium and zinc levels were less frequently reported than ferritin at 3 and 6 months, the BOMSS guidance states that the monitoring of these trace minerals should be considered at least annually. They were therefore not expected to be routinely monitored at the earlier follow up intervals.

Micronutrient Status among Patients Tested

Tables 3 and 4 provide a breakdown of low/deficient micronutrient status for all procedures combined and according to each individual procedure at each follow up interval. The deficiency prevalence estimates for each micronutrient was calculated from patients that had available data for each separate micronutrient ($n=$). Vitamin D was the most commonly reported preoperative micronutrient deficiency, reported in 61.9% of patients with available data (274/443; 95% CI 57.2–66.3). This was followed by low folate, reported in 19% (88/462; 95% CI 15.7–22.9) of patients with available data, while all other preoperative blood tests showed low values in fewer than 5% of the patients tested. For all procedures combined, low vitamin D was reported in 32.9% (23/70; 95% CI 23.0–44.5) of patients tested at 3 months, 30.7% (54/176; 95% CI 24.3–37.8) at 6 months and 24.2% (68/281; 95% CI 19.6–29.5) at 12 months postoperatively. As per the updated BOMSS guidelines which suggest a postoperative target of >75nmol/L for 25-hydroxyvitamin D, 64.3% ($n=45/70$; 95% CI 52.6–74.5) of patients tested at 3 months, 61.5% ($n=99/161$; 95% CI 53.8–68.7) at 6 months and 55.2% ($n=153/277$; 95% CI 49.3–61.0) at 12 months did not meet this vitamin D target level. Anaemia, defined by a low haemoglobin level, was reported in 6.7% (6/89; 95% CI 3.1–13.9) of patients tested at 3 months, 8.6% (17/198; 95% CI 5.4–13.3) at 6 months and 3.8% (12/314; 95% CI 2.2–6.6) at 12 months postoperatively. Although the routine monitoring of trace

Table 2 Pre and postoperative nutritional blood test results reported

	Preoperative ($n = 669$)	3 months postoperative ($n = 394^*$)	6 months postoperative ($n = 469^*$)	12 months postoperative ($n = 480^*$)
<i>Vitamin D</i>	443 (66.2%)	70 (17.8%)	176 (37.5%)	281 (58.5%)
<i>Albumin-adjusted calcium</i>	446 (66.7%)	82 (20.8%)	179 (38.2%)	297 (61.9%)
<i>Parathyroid hormone</i>	216 (32.3%)	54 (13.7%)	108 (23.0%)	130 (27.1%)
<i>Folate</i>	462 (69.1%)	70 (17.8%)	165 (35.2%)	286 (59.6%)
<i>Vitamin B12</i>	466 (69.7%)	61 (15.8%)	144 (31.2%)	254 (53.6%)
<i>Ferritin</i>	270 (40.4%)	77 (19.5%)	167 (35.6%)	192 (40.0%)
<i>Haemoglobin</i>	578 (86.4%)	89 (22.6%)	198 (42.2%)	314 (65.4%)
<i>Zinc</i>	N/A	44 (11.4%)	69 (14.9%)	191 (40.3%)
<i>Copper</i>	N/A	27 (7.0%)	55 (11.9%)	176 (37.1%)
<i>Selenium</i>	N/A	38 (9.8%)	51 (11.0%)	163 (34.4%)
<i>Albumin</i>	558 (83.4%)	92 (23.4%)	194 (41.4%)	316 (65.8%)

*Figures for postoperative vitamin B12, zinc, copper and selenium levels exclude gastric band procedures as these tests are not routinely recommended in the BOMSS guidance [12] (3 months: $n = 386$; 6 months: $n = 462$; 12 months: $n = 474$). N/A = not applicable

Table 3 Reported deficient/low nutritional blood marker status at baseline (pre-operative) and by procedure at 3 months. *PTH*: parathyroid hormone

	Pre-operative	3 months		
		RYGB/OAGB	SG	Total*
<i>Vitamin D</i>	<i>n</i> =443 274 (61.9%)	<i>n</i> =37 10 (27.0%)	<i>n</i> =29 10 (34.5%)	<i>n</i> =70 20 (28.6%)
<i>Albumin-adjusted calcium</i>	<i>n</i> =446 21 (4.7%)	<i>n</i> =48 4 (8.3%)	<i>n</i> =30 2 (6.7%)	<i>n</i> =82 6 (7.3%)
<i>PTH</i> [#]	<i>n</i> =216 3 (1.4%)	<i>n</i> =29 0 (0.0%)	<i>n</i> =21 0 (0.0%)	<i>n</i> =54 0 (0.0%)
<i>Folate</i>	<i>n</i> =462 88 (19.0%)	<i>n</i> =39 0 (0.0%)	<i>n</i> =27 2 (7.4%)	<i>n</i> =70 4 (2.9%)
<i>Vitamin B12</i>	<i>n</i> =466 12 (2.6%)	<i>n</i> =36 3 (8.3%)	<i>n</i> =25 0 (0.0%)	<i>n</i> =61 3 (4.9%)
<i>Ferritin</i>	<i>n</i> =270 14 (5.2%)	<i>n</i> =44 3 (6.8%)	<i>n</i> =29 1 (3.4%)	<i>n</i> =77 4 (5.2%)
<i>Haemoglobin</i>	<i>n</i> =578 26 (4.5%)	<i>n</i> =52 3 (5.8%)	<i>n</i> =33 3 (9.1%)	<i>n</i> =89 6 (6.7%)
<i>Zinc</i> [#]	<i>N/A</i>	<i>n</i> =26 3 (11.5%)	<i>n</i> =18 3 (16.7%)	<i>n</i> =44 6 (13.6%)
<i>Copper</i> [#]	<i>N/A</i>	<i>n</i> =16 0 (0.0%)	<i>n</i> =11 0 (0.0%)	<i>n</i> =27 0 (0.0%)
<i>Selenium</i> [#]	<i>N/A</i>	<i>n</i> =21 1 (4.8%)	<i>n</i> =17 3 (17.6%)	<i>n</i> =38 4 (10.5%)
<i>Albumin</i>	<i>n</i> =558 18 (3.2%)	<i>n</i> =57 2 (3.5%)	<i>n</i> =31 0 (0.0%)	<i>n</i> =92 2 (2.2%)

* Total includes 4 patients who underwent AGB. This procedure is not presented separately in the table due to low sample size. Vitamin B12, zinc, copper and selenium are not requested for AGB

The monitoring of trace minerals < 12 months postoperatively is not explicitly recommended and should be monitored at least on an annual basis. Postoperative monitoring of PTH is also not routinely recommended

minerals is not explicitly recommended 3 and 6 months after MBS in the UK, BOMSS recommends monitoring at regular intervals on an at least annual basis. Therefore, as this may be interpreted differently across centres, blood test data was provided from some centres for these early follow up intervals and included in the analysis. Amongst tested patients, the prevalence of low zinc increased at each subsequent postoperative follow up interval for all procedures combined: 13.6% at 3 months (95% CI 6.4–26.7), 17.4% at 6 months (95% CI 10.2–28.0), 28.8% at 12 months (95% CI 22.8–35.6).

Comparisons between procedure groups are descriptive and unadjusted and should be interpreted with caution. When comparing by procedure, low zinc was more common in the sleeve gastrectomy group than in the gastric bypass group at each postoperative follow up interval (16.7% vs 11.5% at 3 months, 27.6% vs 10% at 6 months, 32.2% and 26% at 12 months). A low selenium level was reported in 10.5% (95% CI 4.2–24.1) of patients tested at 3 months, 29.4% (95% CI 18.7–43.0) at 6 months and 27.6% (95% CI 21.3–34.9) at 12 months postoperatively. The sleeve gastrectomy group had a higher prevalence of low selenium at 3 months (17.6% vs 4.8%) and 6 months (36.4% vs 24.1%) postoperatively,

whereas the gastric bypass group had a higher prevalence at 12 months postoperative (32.2% vs 22.4%).

When comparing preoperative to postoperative micronutrient status, the prevalence of low vitamin D and folate was significantly lower in those tested at 12 months postoperative compared with preoperative levels (McNemar's test: vitamin D, $p < 0.001$; folate, $p = 0.012$). No other statistically significant differences were observed when comparing preoperative and 12-month postoperative micronutrient levels (Table 5). However, these analyses were likely underpowered due to the low prevalence of deficiency for several micronutrients.

The laboratory reference ranges used by individual centres has been included as supplementary material (Table 1).

Discussion

This is the first national multicentre study examining the prevalence of micronutrient deficiency in the first 12 months after MBS and adherence to the updated BOMSS pre- and postoperative nutritional monitoring guidelines in

Table 4 Reported deficient/low nutritional blood marker status by procedure at 6 and 12 months. *PTH: parathyroid hormone*

	6 months			12 months		
	RYGB/ OAGB	SG	Total*	RYGB/ OAGB	SG	Total*
<i>Vitamin D</i>	<i>n</i> = 102 29 (28.4%)	<i>n</i> = 71 24 (33.8%)	<i>n</i> = 176 54 (30.7%)	<i>n</i> = 156 40 (25.6%)	<i>n</i> = 123 27 (22.0%)	<i>n</i> = 281 68 (24.2%)
<i>Albumin adjusted calcium</i>	<i>n</i> = 107 4 (3.7%)	<i>n</i> = 70 0 (0.0%)	<i>n</i> = 179 4 (2.2%)	<i>n</i> = 162 7 (5.6%)	<i>n</i> = 133 4 (3.0%)	<i>n</i> = 297 11 (3.7%)
<i>PTH[#]</i>	<i>n</i> = 63 0 (0.0%)	<i>n</i> = 42 0 (0.0%)	<i>n</i> = 108 0 (0.0%)	<i>n</i> = 80 1 (1.3%)	<i>n</i> = 50 0 (0.0%)	<i>n</i> = 130 1 (0.8%)
<i>Folate</i>	<i>n</i> = 97 7 (7.2%)	<i>n</i> = 66 12 (18.2%)	<i>n</i> = 165 20 (12.1%)	<i>n</i> = 156 6 (3.8%)	<i>n</i> = 128 18 (14.1%)	<i>n</i> = 286 26 (9.1%)
<i>Vitamin B12</i>	<i>n</i> = 93 1 (1.1%)	<i>n</i> = 51 0 (0.0%)	<i>n</i> = 144 1 (0.7%)	<i>n</i> = 141 0 (0.0%)	<i>n</i> = 113 1 (0.9%)	<i>n</i> = 254 1 (0.4%)
<i>Ferritin</i>	<i>n</i> = 96 5 (5.2%)	<i>n</i> = 68 3 (4.4%)	<i>n</i> = 167 8 (4.8%)	<i>n</i> = 115 2 (1.7%)	<i>n</i> = 75 7 (9.3%)	<i>n</i> = 192 9 (4.7%)
<i>Haemoglobin</i>	<i>n</i> = 115 7 (6.1%)	<i>n</i> = 80 10 (12.5%)	<i>n</i> = 198 17 (8.6%)	<i>n</i> = 175 3 (1.7%)	<i>n</i> = 137 9 (6.6%)	<i>n</i> = 314 12 (3.8%)
<i>Zinc[#]</i>	<i>n</i> = 40 4 (10.0%)	<i>n</i> = 29 8 (27.6%)	<i>n</i> = 69 12 (17.4%)	<i>n</i> = 104 27 (26.0%)	<i>n</i> = 87 28 (32.2%)	<i>n</i> = 191 55 (28.8%)
<i>Copper[#]</i>	<i>n</i> = 35 0 (0.0%)	<i>n</i> = 20 0 (0.0%)	<i>n</i> = 55 0 (0.0%)	<i>n</i> = 94 2 (2.1%)	<i>n</i> = 82 2 (2.4%)	<i>n</i> = 176 4 (2.3%)
<i>Selenium[#]</i>	<i>n</i> = 29 7 (24.1%)	<i>n</i> = 22 8 (36.4%)	<i>n</i> = 51 15 (29.4%)	<i>n</i> = 87 28 (32.2%)	<i>n</i> = 76 17 (22.4%)	<i>n</i> = 163 45 (27.6%)
<i>Albumin</i>	<i>n</i> = 116 7 (6.0%)	<i>n</i> = 76 3 (3.9%)	<i>n</i> = 194 10 (5.2%)	<i>n</i> = 175 7 (4.0%)	<i>n</i> = 139 7 (5.0%)	<i>n</i> = 316 14 (4.4%)

* Total includes 2 or 3 patients who underwent AGB. This procedure is not presented separately in the table due to low sample size. Vitamin B12, zinc, copper and selenium are not requested for AGB

The monitoring of trace minerals < 12 months postoperatively is not explicitly recommended and should be monitored at least on an annual basis. Postoperative monitoring of PTH is also not routinely recommended

the UK [12]. This collaboration of 13 MBS centres across England provides a large patient sample number with reflective demographic characteristics comparable to the National Bariatric Surgery Registry [11].

Preoperative Monitoring of Nutritional Bloods

Obesity is a risk factor for micronutrient deficiency. Various mechanisms exist which include poor dietary quality and reduced intake of individual nutrients from the diet, higher

micronutrient requirements (e.g. certain trace minerals involved in macronutrient metabolism), inflammation, and gastrointestinal tract absorption issues [14, 15]. For this reason, BOMSS guidance recommends a detailed nutritional assessment prior to MBS, including haemoglobin, ferritin, folate, vitamin B12, vitamin D, calcium and parathyroid hormone as standard, therefore providing an opportunity to correct any micronutrient deficiencies before surgery is performed [12]. Previous studies have shown that micronutrient deficiencies can affect up to 85% of individuals when screened preoperatively [7–9], highlighting the importance of preoperative nutritional screening. In this study, most patients (77.6%) had a nutritional preoperative blood test of some form. Our data highlight some inconsistencies in preoperative nutritional screening (Table 2), with haemoglobin being the most reported parameter (86.4%) and parathyroid hormone (PTH) being the least reported (32.3%). Of the remaining micronutrient tests, adjusted calcium, folate and vitamin B12 were reported in just under 70% of patients, and ferritin was reported in 40.4%. Vitamin D was the most commonly reported low pre-operative micronutrient level, affecting 61.9% (274/443) of the patients who were tested, which is in-keeping with published literature [16–18]. In cases where PTH was reported preoperatively (*n* = 216), 1 in 5 patients tested had a raised PTH level. This may be

Table 5 Prevalence of low micronutrient levels preoperatively and 12 months postoperatively

	Pre-operative <i>n</i> / <i>N</i> (%)	12 months <i>n</i> / <i>N</i> (%)	<i>p</i> value*
<i>Vitamin D</i>	46/221 (20.8%)	20/221 (9.0%)	<0.001
<i>Albumin adjusted calcium</i>	8/232 (3.4%)	9/232 (3.9%)	1.000
<i>Folate</i>	38/231 (16.5%)	21/231 (9.1%)	0.012
<i>Vitamin B12</i>	6/224 (2.7%)	1/224 (0.4%)	0.125
<i>Ferritin</i>	7/113 (5.3%)	8/113 (6.0%)	1.000
<i>Haemoglobin</i>	13/311 (4.2%)	11/311 (3.5%)	0.791
<i>Albumin</i>	10/303 (3.3%)	14/303 (4.6%)	0.523

* McNemar's test to compare dependent proportions. Data restricted to those who attended 12-month follow up and had measurements on a micronutrient at both baseline and 12 months. Excludes those who had OAGB procedure with a limb length > 150)

related to secondary hyperparathyroidism, correlating with the high prevalence of vitamin D insufficiency/deficiency [19]. The second most prevalent pre-operative micronutrient deficiency was folate, seen in 19% of patients where a folate level was reported ($n = 88/462$). This is also in line with the literature as previous studies have reported a prevalence of 15–30% for folate deficiency in pre-MBS nutritional screening [9]. These findings therefore support the recommendation for preoperative nutritional screening in preparation for MBS. However, our data suggests that there is inconsistency in preoperative nutritional screening, indicating that patients may not be adequately nutritionally optimised prior to having MBS in terms of micronutrient status.

Postoperative Follow Up, Availability of Blood Test Results and Clinician Adherence to Guidelines

The postoperative follow up attendance rate peaked at 90.5% attendance 3 months postoperatively. Due to restrictions placed on in-person contacts whilst transitioning out of the COVID-19 pandemic, consultations were predominantly performed virtually (i.e. telephone or video call), rather than in-person. This may in-part explain the reason for the high level of missing data for postoperative blood test results, given that blood tests were likely not performed during an in-person bariatric clinic visit. Instead, it is likely that blood tests were requested to take place in an alternative setting (e.g. primary care), either leading to results not being available for review by the bariatric team or blood tests not being performed. Despite the safe implementation and reported advantages of remote follow up after MBS [20, 21], MBS centres need to consider the impact of this on blood monitoring to ensure early detection of compromised nutritional status. The BOMSS guidance recommends the monitoring of nutritional biochemistry 3, 6 and 12 months in the first postoperative year to ensure nutritional requirements are met and to reduce the risk of deficiencies [12]. Our results suggest that there is a lack of adequate monitoring of micronutrient status during the early (3 and 6 month) follow intervals. At the 3-month postoperative follow up interval, the least reported routine individual nutritional blood test was vitamin B12 at 15.8% (71/394), with albumin being the most reported at 23.4% (92/394). The availability of routine blood test data increased at the 6-month postoperative follow up interval ranging from 31.2% (vitamin B12) to 42.2% (haemoglobin). Despite some centres reporting data for zinc, copper and selenium at the 3 and 6 months follow up, the BOMSS guidance does not explicitly state that the routine testing of these trace minerals is required at the < 12 month follow up intervals, stating that monitoring serum zinc, copper and selenium levels should be considered at least annually [12]. Selenium was the least reported at the 12-month

postoperative follow up interval at 34.4% (163/480), with albumin (65.8%) and haemoglobin (65.4%) being the most reported ($n = 480$). Another likely factor explaining the lack of postoperative blood tests data is clinician adherence to arranging blood tests. Clinicians were reported as requesting a blood test for 33.7% (134/398) and 60.0% (286/477) of patients who attended follow up appointments at 3 and 6 months respectively. Given the lack of literature on micronutrient status during the early period after MBS (< 12 months), the BOMSS recommendations on the frequency of monitoring is noted as a good practice point [12] and therefore may be interpreted variably by individual centres. The evidence supporting the optimal frequency of micronutrient testing remains limited and it may be the case that early postoperative monitoring can inform supplement dose adjustments and help to prevent more severe nutritional complications longer term. However, the clinical utility and cost-effectiveness of routine testing require further prospective evaluation. Our data shows that MBS centres across England are most adherent to the BOMSS nutritional guidelines for blood screening at the 12 month follow up interval given that 88.4% (433/490) of patients who attended their follow up appointment at 12 months had a blood test requested by a bariatric clinician. It is worth noting that we did not collect data on which clinician(s) was responsible for requesting postoperative blood tests. It is likely that specialist bariatric dietitians provided the majority of the postoperative follow up, however requesting blood tests may be the responsibility of a bariatric surgeon/nurse who may review patients less often outside of the immediate postoperative period.

Postoperative Micronutrient Status

In those tested, vitamin D was the most commonly reported micronutrient to report low levels at each of the follow up intervals, as defined by each centre's local laboratory reference range (typically 25-hydroxyvitamin D < 50nmol/L). Low vitamin D was reported in 32.9% (23/70) of patients tested at 3 months, 30.7% (54/176) at 6 months, and 24.2% (68/281) at 12 months. Vitamin D plays a vital role in the regulation of calcium status and bone metabolism. Alongside osteomalacia, low vitamin D status is now also linked to a host of chronic conditions such as metabolic syndrome, diabetes and cardiovascular disease [22]. Our findings are consistent with other literature on vitamin D status after MBS [17, 18]. When applying the updated 2020 BOMSS guideline target of > 75nmol/L for 25-hydroxyvitamin D, 64.3% ($n = 45/70$) of patients tested at 3 months, 61.5% ($n = 99/161$) at 6 months and 55.2% ($n = 153/277$) at 12 months did not reach the target status for vitamin D. The optimal level for vitamin D status post MBS does not have consensus. It is noteworthy that the prevalence of low vitamin D

after surgery reduced considerably in those tested when compared to preoperative levels, likely due to an increase vitamin D consumption through routine supplementation as the BOMSS guidance suggests individuals may require a supplemented 2000–4000 IU daily dose of vitamin D after sleeve gastrectomy and gastric bypass [12]. In this study, low vitamin D was comparable between sleeve gastrectomy and gastric bypass groups at the 3 month (34.5% vs. 27.0%), 6 month (33.8% vs. 28.4%), and 12 month (22.0% vs. 25.6%) follow up intervals. Both procedures pose a risk to vitamin D status due to reduced dietary intake and gastric acid production [23], however the longer-term risks of low vitamin D after gastric bypass are often greater due to the alterations of the gastrointestinal tract and subsequent negative impact on vitamin D absorption [24]. Vitamin D and PTH work together to control calcium homeostasis, with vitamin D deficiency being associated with secondary hyperparathyroidism and reduced calcium absorption [25]. Low albumin-adjusted calcium levels were not commonly observed in this study. It is worth noting that postoperative PTH levels are only recommended to be tested in the absence of preoperative testing [12].

Despite the recommendation that patients should take a daily complete multivitamin and mineral supplement after sleeve gastrectomy and gastric bypass (including 2 mg copper, 15 mg zinc and selenium) [12], this study identified low selenium and zinc levels amongst patients who underwent testing. However, the extent to which these findings reflect the wider postoperative population is uncertain due to incomplete testing and potential for selective testing. Although the routine monitoring of trace minerals is not explicitly recommended 3 and 6 months after MBS in the UK, BOMSS recommends monitoring at regular intervals on an at least annual basis. Therefore, as this may be interpreted differently across centres, blood test data was provided from some centres for these early follow up intervals and included in the analysis. Of the 38 patients who had selenium tested at 3 months postoperatively, 4 (10.5%) had low levels. This increased to 29.4% at 6 months (15/51). At 12 months post MBS, selenium measurements were available for 163 patients, of whom 27.6% (47 patients) had low levels. Limited literature exists on selenium status after MBS. A meta-analysis performed in 2022 reported a 16% prevalence of selenium deficiency 1-year post MBS [26]. A proportion of gastric bypass patients were reported to have a low selenium level 12 months after surgery in this study; however, selenium measurements were only available for a minority of patients and the representativeness of this group is uncertain. The exclusion of the duodenum and proximal jejunum when performing gastric bypass is a likely contributing factor to selenium deficiency, given the lack of nutrient exposure to absorptive intestinal cells [4]. However, given

that 22.4% of individuals tested in our study also reported low selenium levels 12 months after sleeve gastrectomy where intestinal continuity is maintained, this suggests other factors exist which affect selenium status after MBS. Although it has been suggested that the potential for poor tolerance of selenium-rich foods during the first 12 months after MBS may provide an explanation [27], more exploration is required to understand selenium status after all MBS procedures. Postoperative low zinc was reported in 13.6% (6/44), 17.4% (12/69) and 28.8% (55/191) of patients tested at 3, 6 and 12 months respectively. Interestingly, amongst patients with available zinc measurements, low zinc levels were observed more frequently after sleeve gastrectomy than gastric bypass at all follow up intervals: 16.7% vs. 11.5% at 3 months; 27.6% vs. 10.0% at 6 months; 32.2% vs. 26.0% at 12 months in those tested. However, these findings should be interpreted cautiously given the small sample sizes, potential influence of confounding, centre-level variation, selective testing and differences in supplementation adherence. Similarly to selenium, zinc is also absorbed in the small intestine and is therefore at risk of reduced absorption after gastric bypass.

Our findings highlight a need for future prospective studies to investigate the need for earlier postoperative monitoring of zinc and selenium at the 3 and 6 month follow up intervals. These findings also support the routine monitoring of selenium after sleeve gastrectomy as per current guidelines [12].

Regarding B vitamin status of tested patients, folate deficiency was more prevalent than vitamin B12 deficiency in this study. Low vitamin B12 levels were reported in three patients (4.9%) at 3 months, and in one patient at both 6 months (0.7%) and 12 months (0.4%). The low prevalence of vitamin B12 deficiency in this study is likely explained by the 86.2% and 91.1% reported adherence to vitamin B12 injection therapy at the 6 and 12 month follow up intervals respectively. Due to the reduced absorption of vitamin B12 after sleeve gastrectomy and gastric bypass, routine intramuscular vitamin B12 injections are recommended on a 3-monthly basis [12]. It is likely, however, that some patients would not have yet received their first post-operative vitamin B12 injection when blood was taken at the 3-month follow-up interval. Although this may potentially explain why the prevalence of low vitamin B12 is higher here, only 3/36 patients tested had low vitamin B12 at 3 months postoperatively. Although preoperative screening of vitamin B12 status is advised preoperatively [12], 203 patients (30.3%) were reported to have either not had vitamin B12 status screened or had missing data. Our findings shows decreased prevalence of folate deficiency postoperatively when compared to preoperative levels. This may be because folic acid supplementation of 400–800mcg per day

is recommended after MBS as per BOMSS 2020 guidelines, usually as part of a multivitamin and mineral supplement [12]. A review by Lewis et al. [28], including 14 studies on folate status during the first 12 months after MBS which reported either no change of folate levels compared to baseline, or a reduced prevalence of deficiency 12 months after surgery. MBS impacts folate status in a variety of ways; a reduction in folic acid intake, change in intestinal pH and reduced exposure to absorptive cells in the proximal small bowel. However, folic acid is usually supplemented postoperatively to account for a reduction in consumption and intestinal plasticity allows for postoperative adaptation of folic acid absorption along further along the small bowel [29]. Interestingly, the prevalence of folate deficiency of tested patients was higher after sleeve gastrectomy compared with gastric bypass at all follow up intervals in our study: 7.4% vs. 0.0% at 3 months; 18.2% vs. 7.2% at 6 months; 14.1% vs. 3.8% at 12 months.

Anaemia (defined as low haemoglobin) was reported in 6.7% (6/89) of patients tested at 3 months, 8.6% (17/198) at 6 months and 3.8% ($n = 12/314$) at 12 months. Iron deficiency anaemia can occur after MBS due to reduced dietary intake, reduced secretion of gastric acid and reduced exposure to absorptive cells in the small bowel [30]. Prevalence of iron deficiency, as defined by low ferritin in tested patients, remained stable across the follow-up intervals (5.2% at 3 months, 4.8% at 6 months, 4.7% at 12 months) and was comparable to preoperative prevalence (5.2%). This is a lower prevalence compared to other published literature and may be explained by BOMSS guidance recommendations for daily iron supplementation (e.g. 210 mg ferrous fumarate) after sleeve gastrectomy and gastric bypass, increasing to twice daily for menstruating women [12]. A systematic review and meta-analysis performed by Xia et al. [31] including 6885 patients showed a pooled prevalence for iron deficiency of 14% 1-year following gastric bypass and sleeve gastrectomy. It is worth noting that this review also included serum iron as a diagnostic criterion for iron deficiency.

Patient Reported Adherence to Micronutrient Supplementation

Micronutrient supplementation plays an important role in maintaining an adequate nutritional status after MBS [11]. For this reason, prophylactic use of micronutrient supplementation is recommended by a number of societies to reduce the risk of nutritional deficiency [12, 32, 33]. The updated BOMSS guidance recommends a complete multivitamin and mineral supplement to be taken daily after all MBS procedures, with the addition of separate iron, vitamin D and calcium supplementation following gastric bypass

and sleeve gastrectomy [12]. Many factors can influence the adherence to micronutrient supplementation following MBS, including gastro-intestinal side effects, unsavoury taste, forgetfulness and cost [34–36]; it has been shown that adherence to micronutrient supplementation following MBS is likely to decrease over time [37, 38]. There was substantial missing data regarding reported micronutrient supplement adherence in this study (Table 2), and the available information lacked granularity. Consequently, adherence was defined as patients reported as taking all recommended micronutrient supplements as per the BOMSS guidelines [12]. Reported supplement adherence was similar across all follow up intervals, with approximately two thirds of patients reporting adherence to all recommended supplements.

Strengths and Limitations

This is the first multicentre within the UK study to evaluate the prevalence of micronutrient deficiency 12 months after MBS, alongside adherence to the BOMSS nutritional monitoring guidelines. The findings provide insight into real-world practice across a geographically diverse sample of bariatric centres in England.

This study also has several important limitations. The retrospective use of routinely collected data meant that there was limited control over data quality and completeness, resulting in substantial missing data across multiple variables. This may have introduced selection bias, as patients with available micronutrient data may have differed systematically from those with missing data. The deficiency prevalence estimate for each micronutrient was calculated using patients with available data and therefore may not be generalisable to the entire cohort. The extent of the missing data and the relatively small number of patients reporting micronutrient deficiencies precluded us from undertaking predictive modelling to explore associations between patient characteristics, procedure type, gastric bypass intestinal limb length and the prevalence of postoperative micronutrient deficiency. As a result, comparisons between procedure groups were unadjusted and may be influenced by baseline differences, centre-level variation, selective testing, and differences in supplementation adherence.

Regarding micronutrient supplementation adherence, to ensure consistency across centres and minimise misclassification, we adopted a pragmatic binary approach reflecting whether patients were reported to be taking all recommended micronutrient supplements. This binary categorisation may group together patients with heterogeneous supplementation behaviours and partial adherence, selective omission of certain micronutrients, and variation in dosing could not be

evaluated. Additionally, the study did not explore the effect of dietary intake, intestinal limb length and reasons for patient non-adherence to micronutrient supplementation, nor whether blood deficiencies were associated with clinical symptoms, limiting interpretation of their clinical relevance. For practical reasons, data collection was restricted to 12 months postoperatively, although micronutrient deficiencies may emerge or worsen over longer-term follow-up. The thresholds for deficiency were applied based on the local reporting standards of each centre and the specific assays used to analyse samples were not recorded, therefore cross-centre comparability of deficiency prevalence may be affected. Data on inflammatory markers (e.g., C-reactive protein) and complementary biomarkers relevant to micronutrient interpretation were not collected. Consequently, we were unable to account for the potential influence of inflammation or altered micronutrient transport on reported micronutrient levels. Finally, participating centres may represent those that are more engaged with professional networks, are more motivated to contribute to collaborative research, and may have comparatively well-developed follow-up and monitoring practices. As a result, the findings may not fully reflect the variability in care across all MBS centres.

Conclusion

Our findings demonstrate that micronutrient deficiencies, particularly vitamin D, folate, selenium, and zinc are frequently observed amongst patients with available biochemical data within the first 12 months following MBS. In the patients tested, deficiencies in folate, selenium and zinc were observed more frequently in the sleeve gastrectomy group than in the gastric bypass group, highlighting that the risk of micronutrient deficiency after MBS may extend beyond hypoabsorption. However, these descriptive findings should be interpreted cautiously given the potential influence of confounding, centre-level variation, selective testing and differences in supplementation adherence. This highlights the importance of micronutrient monitoring regardless of procedure type.

Low selenium and zinc levels were observed in a notable proportion of patients with available trace mineral data, potentially indicating an under-recognised problem. However, due to incomplete testing and potential for selective testing, these findings should be interpreted cautiously and require confirmation in prospective studies with larger datasets and systematic follow-up and micronutrient assessment. Future studies are also required to explore the clinical implications and evaluate the earlier and more systematic monitoring of trace minerals after MBS. Our findings also show that MBS centres across England request nutritional

bloods most frequently at the 12 month follow up interval, compared with the 3- and 6-month intervals.

These results highlight the need for improved implementation of national guidelines during the first 12 months after MBS, greater standardisation of postoperative monitoring practices, and longer-term follow-up studies with prospective data collection and balanced centre participation to better understand the trajectory and clinical impact of micronutrient deficiency after MBS.

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Author Contributions GH and SA were responsible for initial study concept and design. CP and SA conducted statistical analysis. GH, SA, CP, HMP, MOK and DJP contributed to the writing of the manuscript and response to reviewer comments. All authors reviewed the final version of the manuscript.

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Data Availability Availability requests for data collected during this study will be considered by the corresponding author.

Declarations

Ethics approval and consent to participate Ethical approval for this study was granted by Coventry University Research Ethics Committee on 19th November 2025 (reference number: P190247). All data was anonymised at site level and stored in a password protected file. As this was a retrospective study of routinely collected data, informed consent was not required.

Competing interests GH is a member of the BOMSS National Bariatric Surgery Registry Committee. SA is an Integrated Health committee member for the IFSO European Chapter and Bariatric Officer for the BDA Obesity Specialist Group. She has received honoraria for educational events or consultancy from Johnson & Johnson, Boston Scientific, and AstraZeneca. MOK is chair for the Association for the Study of Obesity Board of Trustees, British Dietetic Association Obesity Specialist Group social media officer and advisory panel member for the UK Coalition for People Living with Obesity. HMP is a BOMSS council member and an advisory panel member for the UK Coalition for People Living with Obesity. She has received honoraria for educational events or ad hoc consultancy from Johnson & Johnson, Novo Nordisk, Boston Scientific, AbbVie and Radcliffe Group. HMP was a member of the NICE obesity clinical guidelines NG246 committee and NICE obesity quality standards for obesity QS212 committee. DJP has been funded by the Royal College of Surgeons of England. He receives consulting fees from Johnson and Johnson, GSK, Novo

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