

## **Supplementary Material**

### **Exclusions from the analysis cohort**

The analysis cohort included 226 participants (RYGB n=161, VSG n=65), excluding 14 who underwent adjustable gastric banding and 2 who underwent VSG with preexisting conditions that could impact nutritional biomarkers (1 with osteogenesis imperfecta and 1 with anemia of chronic disease). Three participants subsequently developed chronic inflammatory systemic illness, which may influence nutritional biomarkers: multiple sclerosis (n=2, data excluded from month 48 onwards and month 60 only, respectively) and juvenile rheumatoid arthritis (n=1, data excluded from month 24 onwards).

### **Supplementary Statistical Analyses**

Analyses to identify predictors of nutritional status: The GLMM approach was used to identify predictors of nutritional status 1 to 5 years post-operatively after weight stabilization. Prespecified variables included visit, surgery type, sex, race, caregiver educational level and baseline nutritional level as fixed effects, and study center as random effects. Visit-by-surgery interaction terms were not significant and therefore excluded from final models. Weight change between visits and self-reported multivitamin use were included as time-varying covariates. Additional variables were included as time-varying covariates for specific models: acid suppression medication for ferritin, transferrin and vitamin B12; hsCRP for ferritin and transferrin; vitamin D supplement usage for vitamin D and PTH; vitamin B12 supplement usage for vitamin B12; and calcium supplement usage for PTH.

Sensitivity analyses and analyses to account for missing data: Missing data were accounted for by use of the GLMM approach incorporating maximum likelihood estimation and assuming missing at random. The number of observations at each time-point for each nutritional

variable is included in the tables. Additionally, sensitivity analyses were carried out using multiple imputation. Results reported are from models that do not include multiple imputation. The sensitivity analyses, conducted using multiple imputation methods, did not alter the interpretation of the findings in this study (data not shown).<sup>15</sup>

Sensitivity analyses for models examining pregnancy and menstrual frequency: Models were fitted for both the continuous and categorical expression for each nutrient biomarker. Pregnancy status at each visit was considered positive in the model if the woman was either currently pregnant or within 6-months post-partum. Excluding the visits for women affected by pregnancy and/or low menstrual frequency also did not alter the interpretation of the findings except that weight gain was now associated with increasing B12 level (p=0.04).

**Supplemental Table 1: Prevalence of abnormal values in nutritional measures over the five years after gastric bypass or sleeve gastrectomy surgery in adolescents.**

Visit	Baseline	6 months	Year 1	Year 2	Year 3	Year 4	Year 5	P-value for comparison of values between visits †		
Abnormal nutritional biomarker	n (%) [95%CI]	n (%) [95%CI]	n (%) [95%CI]	n (%) [95%CI]	n (%) [95%CI]	n (%) [95%CI]	n (%) [95%CI]	Baseline to 1y	1y to 5y linear trend	Baseline to 5y
<b>Ferritin: &lt;10 ug/L females and &lt;20 ug/L males</b>										
Gastric Bypass	4 (2.5) [0.7, 6.3] N=160	23 (16.9) [10.6, 23.2] N=136	40 (28.2) [21.0, 35.6] N=142	72 (54.6) [46.0, 63.0] N=132	83 (64.3) [56.1, 72.6] N=129	84 (70.0) [61.8, 78.2] N=120	87 (71.3) [63.3, 79.3] N=122	<0.0001	<0.0001	<0.0001
Sleeve Gastrectomy	7 (11.1) [3.3, 18.9] N=63	9 (17.3) [7.0, 27.6] N=52	13 (23.6) [12.4, 37.0] N=55	18 (36.7) [23.2, 50.2] N=49	14 (31.8) [18.1, 45.6] N=44	24 (49.0) [35.0, 63.0] N=49	19 (45.2) [30.2, 60.3] N=42	ns 0.20	0.01	0.002
<b>Transferrin: &gt; 382 mg/d females and &gt; 392 mg/dL males</b>										
Gastric Bypass	1 (0.6) [0, 1.8] N=160	2 (1.5) [0, 3.5] N=136	5 (3.5) [0.5, 6.6] N=142	11 (8.3) [3.6, 13.0] N=132	17 (13.2) [7.3, 19.0] N=129	18 (15.0) [8.6, 21.4] N=120	19 (15.6) [9.1, 22.0] N=122	ns 0.69	<0.0001	0.02
Sleeve Gastrectomy	0 na N=63	0 na N=51	0 na N=55	0 na N=49	0 na N=44	3 (6.1) [0, 12.8] N=42	2 (4.8) [0, 11.2] N=42	Not estimable	ns 0.07	Not estimable
<b>Vitamin B12: &lt; 145 pg/mL</b>										
Gastric Bypass	1 (0.6) [0, 1.9] N=159	3 (2.2) [0, 4.7] N=136	7 (4.9) [1.4, 8.5] N=142	14 (10.6) [5.4, 15.9] N=132	10 (7.8) [3.1, 12.4] N=129	20 (16.7) [10.0, 23.3] N=120	14 (11.5) [5.8, 17.1] N=122	ns 0.45	0.003	ns 0.06
Sleeve Gastrectomy	0 na N=63	2 (3.8) [0, 9.1] N=52	4 (7.3) [0.4, 14.1] N=55	1 (2.0) [0, 6.0] N=49	3 (6.8) [0, 14.3] N=44	3 (6.1) [0, 12.8] N=49	3 (7.1) [0, 14.9] N=42	Not estimable	ns 0.72	Not estimable
<b>Vitamin B1: erythrocyte transketolase activity coefficient ≥1.30</b>										
Gastric Bypass	2 (1.3) [0, 3.1] N=154	1 (0.8) [0, 2.2] N=133	3 (2.2) [0, 4.6] N=137	1 (0.8) [0, 2.3] N=126	1 (0.8) [0, 2.3] N=127	1 (0.9) [0, 2.5] N=116	1 (0.9) [0, 2.6] N=113	Not estimable	Not estimable	Not estimable
Sleeve Gastrectomy	0 na N=61	1 (2.0) [0, 5.8] N=51	0 na N=56	0 na N=48	0 na N=44	0 na N=43	0 na N=39	Not estimable	Not estimable	Not estimable
<b>Folate: ≤ 5.8 ng/mL</b>										
Gastric Bypass	4 (2.5) [0.1, 5.0] N=158	22 (16.2) [10.0, 22.4] N=136	13 (9.2) [4.4, 13.9] N=142	7 (5.3) [1.5, 9.2] N=131	6 (4.7) [1.0, 8.3] N=129	2 (1.7) [0, 4.0] N=120	1 (0.8) [0, 2.4] N=122	ns 0.19	0.0007	ns 0.95
Sleeve Gastrectomy	1 (1.6) [0, 4.7]	8 (15.4) [5.6, 25.2]	10 (18.5) [8.2, 28.9]	4 (8.2) [0.5, 15.8]	4 (9.1) [0.6, 17.6]	3 (6.2) [0, 13.1]	2 (4.8) [0, 11.2]	ns 0.09	0.04	ns 0.98

	N=62	N=52	N=54	N=49	N=44	N=48	N=42			
<b>Vitamin A: &lt; 301 ug/L</b>										
Gastric Bypass	9 (5.7) [2.1, 9.3] N=158	28 (20.9) [14.0, 27.8] N=134	19 (13.4) [7.8, 19.0] N=142	24 (18.3) [11.7, 24.9] N=131	21 (16.5) [10.1, 23.0] N=127	21 (17.5) [10.7, 24.3] N=120	19 (15.7) [9.2, 22.2] N=121	ns 0.10	ns 0.67	ns 0.09
Sleeve	3 (4.9) [0, 10.3] N=61	2 (4.0) [0, 9.4] N=50	2 (3.6) [0, 8.6] N=55	1 (2.1) [0, 6.1] N=48	2 (4.5) [0, 10.7] N=44	2 (4.1) [0, 9.6] N=49	3 (7.0) [0, 14.6] N=43	ns 0.99	ns 0.31	ns 0.99
<b>25-OH Vitamin D: &lt; 20.1 ng/mL</b>										
Gastric Bypass	71 (44.6) [36.9, 52.4] N=159	42 (31.3) [23.3, 39.2] N=134	52 (36.6) [28.7, 44.5] N=142	64 (48.9) [40.3, 57.4] N=131	63 (48.8) [40.2, 57.5] N=129	63 (52.5) [43.6, 61.4] N=120	61 (51.3) [42.3, 60.2] N=119	ns 0.54	0.005	ns 0.82
Sleeve	12 (19.4) [9.5, 29.2] N=62	12 (23.5) [11.9, 35.2] N=51	13 (23.6) [12.4, 34.9] N=55	17 (34.7) [21.4, 48.0] N=49	15 (34.1) [20.1, 48.1] N=44	14 (29.2) [16.3, 42.0] N=48	14 (33.3) [19.1, 47.6] N=42	ns 0.99	ns 0.43	ns 0.70
<b>PTH: &gt; 88 pg/mL</b>										
Gastric Bypass	17 (10.7) [5.9, 15.5] N=159	6 (4.4) [1.0, 7.9] N=135	8 (5.6) [1.8, 9.4] N=142	11 (8.4) [3.6, 13.2] N=131	16 (12.4) [6.7, 18.1] N=129	19 (16.1) [9.5, 22.7] N=118	20 (16.4) [9.8, 23.0] N=122	ns 0.65	0.001	ns 0.73
Sleeve	1 (1.6) [0, 4.7] N=62	0 na N=50	1 (1.8) [0, 5.3] N=55	1 (2.0) [0, 6.0] N=48	1 (2.3) [0, 6.7] N=44	1 (2.1) [0, 6.3] N=47	0 na N=41	Not estimable	Not estimable	Not estimable
<b>Albumin: &lt; 3.5 g/dL</b>										
Gastric Bypass	7 (4.4) [1.2, 7.5] N=160	0 na N=138	0 na N=142	2 (1.5) [0, 3.6] N=133	0 na N=128	1 (0.8) [0, 2.4] N=122	3 (2.5) [0, 5.2] N=122	Not estimable	Not estimable	Not estimable
Sleeve	0 na N=63	0 na N=52	1 (1.8) [0, 5.3] N=55	1 (2.0) [0, 6.0] N=49	0 na N=44	1 (2.0) [0, 6.0] N=49	1 (2.3) [0, 6.7] N=44	Not estimable	Not estimable	Not estimable
<b>hs-CRP: &gt;1 mg/dL</b>										
Gastric Bypass	44 (27.5) [20.6, 34.4] N=160	13 (9.5) [4.6, 14.4] N=137	7 (4.9) [2.0, 9.9] N=142	7 (5.3) [1.5, 9.2] N=131	7 (5.4) [1.5, 9.3] N=129	8 (6.6) [2.2, 11.0] N=121	11 (9.1) [4.0, 14.2] N=121	<0.0001 0.18	ns 0.18	0.0008
Sleeve	12 (19.0) [9.4, 28.7] N=63	7 (13.5) [4.2, 22.7] N=52	6 (10.9) [2.7, 19.2] N=55	4 (8.2) [2.2, 19.6] N=49	4 (9.1) [2.5, 21.7] N=44	6 (12.2) [3.1, 21.4] N=49	6 (14.0) [3.6, 24.3] N=43	ns 0.72	ns 0.36	ns 0.99
<b>Nutrient Deficiency 2 or more deficiencies</b>										
Gastric Bypass	19 (11.9) [6.9, 16.9] N=160	31 (22.5) [15.5, 29.4] N=138	40 (28.2) [20.8, 35.6] N=142	61 (45.2) [36.8, 53.6] N=135	67 (51.2) [42.6, 59.7] N=131	67 (53.6) [44.9, 62.3] N=125	73 (58.9) [50.2, 67.5] N=124	0.003	<0.0001	<0.0001
Sleeve	4 (6.4) [0.3, 12.4]	9 (17.3) [7.0, 27.6]	10 (17.9) [7.8, 27.9]	11 (22.4) [10.8, 34.1]	9 (20.0) [8.3, 31.7]	9 (18.4) [7.5, 29.2]	12 (27.3) [14.1, 40.4]	ns 0.34	ns 0.45	ns 0.09

	N=63	N=52	N=56	N=49	N=45	N=49	N=44			
<b>Nutrient Deficiency 3 or more deficiencies</b>										
Gastric Bypass	5 (3.1) [1.0, 7.1] N=160	14 (10.1) [5.1, 15.2] N=138	8 (5.6) [1.8, 9.4] N=142	22 (16.3) [10.1, 22.5] N=135	22 (16.8) [10.4, 23.2] N=131	28 (22.4) [15.1, 29.7] N=125	24 (19.4) [12.4, 26.3] N=124	ns 0.88	0.0001	0.0005
Sleeve	1 (1.6)	1 (1.9)	3 (5.4)	3 (6.1)	3 (6.7)	4 (8.2)	1 (2.3)	ns	ns	ns
Gastrectomy	[0, 4.7] N=63	[0, 10.3] N=52	[1.1, 14.9] N=56	[1.3, 16.9] N=49	[1.4, 18.3] N=45	[2.3, 19.6] N=49	[0, 12.0] N=44	0.94	0.72	1.00

† P-values are from generalized linear mixed models performed using a logit link function. Tukey-Kramer adjustment used when testing differences between baseline and year 1 and baseline and year 5 time-points. A linear model was fitted to test for trend between year 1 and year 5.

**Supplemental Table 2: Reported intake of nutrient supplements, nutritionally-relevant medications, pregnancy and menstrual frequency over the 5 years after bariatric surgery, [n/N (%)]**

Variable	Baseline	6 months	Year 1	Year 2	Year 3	Year 4	Year 5
<b>Supplement Intake</b>							
<b>Multi-vitamins</b>							
Gastric Bypass	106/157 (68%)	130/142 (92%)	128/140 (91%)	102/135 (76%)	87/129 (64%)	81/126 (64%)	75/131 (57%)
Sleeve Gastrectomy	57/62 (92%)	47/52 (90%)	45/55 (82%)	33/51 (65%)	28/48 (58%)	33/50 (66%)	20/48 (42%)
<b>Calcium</b>							
Gastric Bypass	53/153 (35%)	118/141 (84%)	111/140 (79%)	85/133 (65%)	68/127 (54%)	60/125 (48%)	46/129 (36%)
Sleeve Gastrectomy	29/62 (47%)	47/52 (90%)	37/55 (67%)	27/50 (54%)	20/48 (42%)	13/50 (26%)	12/48 (25%)
<b>Vitamin D</b>							
Gastric Bypass	24/124 (19%)	39/133 (29%)	44/134 (33%)	42/130 (32%)	36/123 (29%)	35/124 (28%)	35/127 (28%)
Sleeve Gastrectomy	19/55 (34%)	32/47 (68%)	24/53 (45%)	21/50 (42%)	25/47 (53%)	10/50 (20%)	13/48 (27%)
<b>Iron</b>							
Gastric Bypass	13/149 (9%)	37/142 (26%)	40/138 (29%)	39/131 (30%)	38/126 (30%)	41/127 (32%)	37/129 (29%)
Sleeve Gastrectomy	15/56 (27%)	13/48 (27%)	16/55 (29%)	12/50 (24%)	10/48 (21%)	11/50 (22%)	10/48 (21%)
<b>B12 oral</b>							
Gastric Bypass	32/150 (21%)	63/143 (44%)	52/137 (38%)	51/133 (38%)	34/125 (27%)	40/125 (32%)	34/127 (27%)
Sleeve Gastrectomy	13/57 (23%)	32/48 (67%)	29/54 (54%)	24/50 (48%)	17/48 (35%)	13/50 (26%)	8/48 (17%)
<b>B12 shot</b>							
Gastric Bypass	1/160 (0.6%)	23/144 (16%)	25/1 (18%)	27/136 (20%)	22/129 (17%)	26/129 (20%)	23/135 (17%)
Sleeve Gastrectomy	0/62 (0%)	2/52 (4%)	3/55 (5%)	5/51 (10%)	6/48 (12%)	9/53 (17%)	13/48 (27%)
<b>Either B12 oral or shot</b>							
Gastric Bypass	33/160 (21%)	82/144 (57%)	73/140 (52%)	70/136 (52%)	54/129 (42%)	56/129 (43%)	53/135 (39%)
Sleeve Gastrectomy	13/62 (21%)	32/52 (62%)	31/55 (56%)	28/51 (55%)	22/48 (46%)	20/53 (38%)	18/48 (38%)
<b>Nutritionally Relevant Medication Intake</b>							
<b>Metformin</b>							
Gastric Bypass	43/161 (27%)	5/145 (3%)	5/144 (4%)	1/139 (1%)	0/132	1/132 (1%)	1/137 (1%)
Sleeve Gastrectomy	15/65 (23%)	2/53 (4%)	1/59 (2%)	1/51 (2%)	1/49 (2%)	2/53 (4%)	1/50 (2%)

**Acid Suppression**

Gastric Bypass	24/161 (15%)	53/145 (37%)	30/144 (21%)	19/139 (14%)	14/132 (11%)	8/132 (6%)	11/137 (8%)
Sleeve Gastrectomy	9/65 (14%)	11/53 (21%)	10/59 (17%)	5/51 (10%)	4/49 (8%)	5/53 (9%)	2/50 (4%)

**Females only****Pregnancy**

Gastric Bypass	0/126 (0%)	0/126 (0%)	2/126 (2%)	7/126 (6%)	6/126 (5%)	11/125 (9%)	10/124 (8%)
Sleeve Gastrectomy	0/44 (0%)	1/44 (2%)	2/44 (5%)	3/43 (7%)	1/43 (2%)	3/43 (7%)	3/43 (7%)

**Periods/Year**

Gastric Bypass	N=116	--	N=108	N=111	N=101	N=105	N=105
0-3	18 (16%)		20 (18%)	20 (18%)	13 (13%)	18 (17%)	22 (21%)
4-9	30 (26%)		17 (16%)	21 (19%)	26 (26%)	24 (23%)	26 (25%)
10+	68 (59%)		71 (66%)	70 (63%)	62 (61%)	63 (60%)	57 (54%)
Sleeve Gastrectomy	N=40	--	N=32	N=30	N=32	N=33	N=30
0-3	9 (22%)		6 (19%)	6 (20%)	7 (22%)	4 (12%)	4 (13%)
4-9	8 (20%)		7 (22%)	6 (20%)	6 (19%)	7 (21%)	9 (30%)
10+	23 (58%)		19 (59%)	18 (60%)	19 (59%)	22 (67%)	17 (57%)

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