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► To cite this version:

Eric O. Verger, Judith Aron-Wisnewsky, Maria Carlota Dao, Brandon D. Kayser, Jean-Michel Oppert, et al. Micronutrient and Protein Deficiencies After Gastric Bypass and Sleeve Gastrectomy: a one-year Follow-up. *Obesity Surgery*, 2016, 26 (4), pp.785-796. 10.1007/s11695-015-1803-7. hal-01297330

HAL Id: hal-01297330

<https://hal.sorbonne-universite.fr/hal-01297330>

Submitted on 4 Apr 2016

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Micronutrient and protein deficiencies after gastric bypass and sleeve gastrectomy: a one-year follow-up

Original Contribution

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Running title: Malnutrition after surgery

Financial Support: This project is supported by the « Contrat de Recherche Clinique » from Health ministry (CRC Fibrota P100503 – IDRCB 2011-A00759-32, recorded on clinical trial website (NCT: NCT01655017), as well as by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement HEALTH-F4-2012-305312 (Metacardis) and the National Agency of Research (Investissement D'Avenir, ANR-10-IAHU-05). JAW received a grant from Institut Appert and from Nestlé research. The authors declare that they have no conflict of interest.

The authors wish to thank Ms Agathe Arlotti for the coordination of programs on bariatric surgery (BARICAN program), Ms Valentine Lemoine for her help in the follow-up of the patients and Dr Florence Marchelli who contributed to clinical and biological database constitution.

1 **ABSTRACT**

2 **Background:** Roux-en-Y gastric bypass (GBP) and sleeve gastrectomy (SG) have increased
3 dramatically, potentially increasing the prevalence of nutritional deficiencies. The aim of this
4 study was to analyze the effects of food restriction during the first year (reviewer #1,
5 comment #1) after bariatric surgery (BS) on nutritional parameters.

6 **Methods:** 22 and 30 obese patients undergoing GBP and SG were prospectively followed at
7 baseline and three, six and twelve months after BS (N=14 and N=19 at T12) (reviewer #1,
8 comments #2&3). We evaluated food intake and nutrient adequacy (T0, T3, T12), as well as
9 serum vitamins and minerals concentration (T0, T3, T6, T12).

10 **Results:** At baseline, GBP and SG patients had similar clinical characteristics, food intake,
11 nutrient adequacy and serum concentration. The drastic energy and food reduction led to very
12 low probabilities of adequacy for nutrients similar in both models (T3, T12). Serum analysis
13 demonstrated a continuous decrease in prealbumin during the follow-up, indicating mild
14 protein depletion in 37% and 38% of GBP patients and 57% and 52% of SG patients,
15 respectively at T3 and T12 (reviewer #1, comments #5,6&7). Conversely, despite the low
16 probabilities of adequacy observed at T3 and T12, systematic multivitamin and mineral
17 supplementation after GBP and SG prevented most nutritional deficiencies.

18 **Conclusion:** GBP and SG have comparable effects in terms of energy and food restriction,
19 and subsequent risk of micronutrient and protein deficiencies in the first year post BS. Such
20 results advocate for a cautious monitoring of protein intake after GPB and SG and a
21 systematic multivitamin and mineral supplementation in the first year after SG.

22
23 **Keywords:** Bariatric surgery; Roux-en-Y Gastric Bypass; Sleeve gastrectomy; Protein
24 deficiency; Multivitamin and mineral supplementation.

26 INTRODUCTION

27 Among the few therapeutic tools to treat morbid obesity, bariatric surgery (BS)
28 appears to be the most effective strategy as demonstrated by its ability to obtain major and
29 sustainable weight loss along with significant improvement of obesity related-comorbidities
30 [1,2]. As a result, the number of interventions has dramatically risen worldwide, and Roux-
31 en-Y Gastric Bypass (GBP) and Sleeve Gastrectomy (SG) represented respectively 47% and
32 28% of the 340,000 BS performed in 2011 [3]. Since 2008, SG has emerged to such an extent
33 that it has become the most common procedure in several countries, as is the case in France
34 [3]. Although the two surgical techniques and their mechanisms of action differ, they appear
35 to be equally safe and both induce significant weight loss post-surgery [4].

36 **GBP includes diet restriction as well as the bypass of the proximal part of the jejunum**
37 **involved in nutrient absorption whereas SG is less invasive and principally restricts the**
38 **volume of the stomach [5] (reviewer #2, comment #4).** Therefore SG, compared to GBP,
39 might be viewed as less likely to exacerbate the risk of micronutrient deficiencies in obese
40 patients who are already prone to such deficiencies before surgery [6]. Nevertheless, some
41 studies have demonstrated a considerably higher prevalence of nutrient deficiencies after SG
42 [7–11]. Others, comparing GBP and SG, found quite similar prevalence after both procedures
43 [12–16]. Although study designs differed, these converging results highlight the importance
44 of daily multivitamin and mineral supplementation after both procedures, at least in the first
45 year for SG, in accordance with the latest US guidelines [17]. While the previously mentioned
46 studies evaluated nutrient deficiencies using serum biomarker concentrations, only very few
47 have evaluated food and nutrient intake after GBP and SG: Freeman *et al.* evaluated food
48 intake two to four years after surgery [18], Moizé *et al.* and Coupaye *et al.* evaluated the
49 overall macronutrient intake during one year after BS but did not quantify micronutrient

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intake [15,19], and Moizé *et al.* evaluated macronutrient and some selected mineral intake during five years after BS [14].

Therefore, we aimed to analyze food restriction effects on the nutritional adequacy of the diet, on macro and micronutrient intake evolution as well as their consequences in terms of bioclinical evolution and micronutrient serum level during one year after both GBP and SG.

MATERIAL AND METHODS

Patients

Obese candidates for either GBP or SG according to the international bariatric surgery guidelines [20] (i.e. body mass index (BMI) $\geq 40 \text{ kg/m}^2$, or $\geq 35 \text{ kg/m}^2$ with at least one severe obesity-related comorbidity) were treated in the Obesity Unit of Pitié-Salpêtrière Hospital, Institute of Cardio-metabolism and Nutrition, ICAN, Paris, France. Patients determined the choice of technique, and advised by a multidisciplinary panel, from the hospital based on medical history, level of corpulence and obesity-related comorbidity. Weight stable patients were enrolled consecutively in this prospective non-randomized study from January 2012. Hotel-Dieu hospital ethics committee approved the clinical protocol (number P100503 – IDRCB 2011-A00759-32) which was recorded on clinical trial website (NCT: NCT01655017). Subjects gave their written informed consent prior to the study inclusion.

Medical history and clinical evaluation were obtained at baseline and during the follow-up at three (T3), six (T6) and twelve months (T12) as described elsewhere [21] (reviewer #1, comment #1). Anthropometric parameters were estimated by whole-body fan-beam DXA scanning (Hologic Discovery W, software v12.6, 2; Hologic, Bedford, MA), as previously described [22]. Variables from DXA used in the analyses were total and appendicular fat free mass (FFM, in kg), and total and appendicular fat mass (FM, in kg),

75 where appendicular FFM (or FM) was calculated as the sum of FFM (or FM) from both arms
76 and both legs. Basal metabolic rate (BMR) was assessed with indirect calorimetry (Deltatrac
77 II monitor, Datex Instrumentarium Corp., Helsinki, Finland) enabling the evaluation of
78 underreporting of dietary intake [23].

80 **Dietary data and nutrient intakes**

81 At baseline, T3 and T12, patients completed three consecutive web-based 24h dietary
82 records as described elsewhere [24], including two weekdays and one day on the weekend
83 whenever possible. All foods and beverages consumed at breakfast, lunch, dinner and snacks
84 were recorded. Validated photographs enabled patients to estimate portion size for each
85 reported food and beverage item [25]. Patients were also asked to indicate multivitamin and
86 mineral supplements use, specifying the product name and amount, following the nutritional
87 deficiency prevention treatment prescribed for every patient at our center, as described in
88 [26]. This includes supplementation during two weeks before surgery of vitamin D (once
89 4×100,000 IU), thiamin (250 mg/day), and vitamin B-12 (250µg/day). Fifteen days post-GBP
90 and SG, multivitamin and mineral supplements including Azinc “Forme et vitalité”® (two
91 capsules per day, containing 800 µg vitamin A, 1.4mg thiamin, 200 µg folate, 1µg vitamin B-
92 12, 120 mg vitamin C, 200 IU vitamin D, 8 mg iron and 15 mg zinc), iron (2×80 mg/ day),
93 vitamin D (800 IU/day), and calcium (1,000mg/day) were started and continued for the first
94 year in both BS procedures. Intake of nutrients derived from food were calculated using an
95 updated version of the French database CIQUAL 2008 [27] which included more than 3,400
96 different food items. Nutrient intakes from multivitamin and mineral supplements were
97 calculated using nutrient profile based on the product name. Ingested foods were categorized
98 into 4 main food groups when possible: (i) fruit and vegetables, (ii) starchy foods, (iii) dairy
99 products, and (iv) meat and fish. The food groups were defined according to the French

100 National Nutrition and Health Program [28] and expressed in servings per day based on
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2 101 standard serving sizes [29].
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6 7 103 **Nutrient adequacy of the diet**

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9 104 Nutrient intake adequacy for each patient was calculated using the PANDiet index
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11 105 [30]. Briefly, probability of adequacy for each nutrient was calculated, ranging from 0 to 1,
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14 106 where 1 represents a 100% probability that the usual intake is adequate (i.e. it satisfies the
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16 107 requirement or is not excessive compared to a reference value). According to this definition,
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19 108 the probabilities of adequacy were computed to obtain the Adequacy sub-score (the higher,
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21 109 the better the intake satisfies the nutrient requirements) and the Moderation sub-score (the
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24 110 higher, the less likely the intake is excessive). The PANDiet score is taken as the mean of the
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26 111 Adequacy and Moderation sub-scores, and ranges from 0 to 100; the higher the score, the
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28 112 better the nutrient adequacy of the diet. As reference values, we used French nutritional
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31 113 recommendations for healthy adults or European Union values when specific
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34 114 recommendations were lacking.
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37 38 39 116 **Biochemical analyses**

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41 117 Blood samples were collected after an overnight fast to measure biochemical
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43 118 parameters using routine techniques as described [31]. Blood count and iron metabolism
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46 119 markers (i.e. ferritin, iron, transferrin, and saturation coefficient) were assessed using routine
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48 120 care method (nephelemetry (reviewer #1, comment #9), ferrozine colorimetry and
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51 121 immunoturbidimetry respectively). Prealbumin was assessed by immunoturbidimetry. Serum
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53 122 concentrations of 25(OH)-vitamin-D3 and parathyroid hormone (PTH) were measured by
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56 123 chemiluminescent assay (310600 Liaison XL Diasorin and 11972103 Modular E 170 Roche,
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58 124 respectively), vitamin B-12 and folate were assessed using immunoanalysis ECL sandwich,
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125 and thiamin and vitamin B-6 were assessed using HPLC [6]. Vitamin and mineral deficiencies
126 were defined as a result below the lower normal value given by the manufacturer [32].
127 Secondary hyperparathyroidism was defined as an elevated PTH, above the high normal
128 laboratory value. All measurements were conducted at baseline, T3, T6 and T12 (except for
129 25(OH)-vitamin-D3, PTH, thiamin, folate and vitamin B-12 at T3, and PTH at T6).

131 **Statistical analyses**

132 Continuous variables are presented as median and interquartile range (IQR) and
133 frequencies as percentages (reviewer #2, comment #2). Mann-Whitney and paired Wilcoxon
134 rank-sum tests were, respectively, used to compare continuous variables between surgical
135 groups and time-points. Chi-squared and McNemar tests were used to compare frequencies
136 between surgical groups and time-points, respectively. An overall α level of 5% was used for
137 statistical tests following Holm-Bonferroni correction. These analyses were conducted on
138 both the patients who completed T3 and T6, and on the patients who completed T3, T6 and
139 T12 (reviewer #1, comment #1). Since no significant difference was observed between two
140 groups of patients both at baseline, and during the follow-up at T3 and T6, outcomes are
141 merged when presented on tables and figures. All analyses were performed using Statistical
142 Analysis Systems statistical software package version 9.3 (SAS Institute, Cary, NC, SA)
143 (reviewer #2, comment #3).

145 **RESULTS**

146 **Clinical characteristics**

147 Fifty-two patients were included in this study (22 GBP and 30 SG). All of them
148 completed the first six months follow-up of this study (T3 and T6), and 33 completed the one
149 year follow-up (T3, T6 and T12; 14 GBP and 19 SG) (reviewer #1, comment #1).

150 Importantly, the two groups were similar at baseline regarding sex, age, corpulence and body
151 composition (Table 1). Likewise, the severity of obesity related-comorbidities was similar in
152 the two groups, except for glucose intolerance, which was significantly more prevalent in the
153 GBP group (Table 1).

154 As expected, BS induced significant weight loss in both surgical techniques, however
155 GBP led to a significantly greater weight loss at T6 and T12 compared to SG (Table 1). More
156 specifically, the total and appendicular FFM (in kg) significantly decreased at T3 and then
157 stabilized at T6 and T12 in the two groups, while the total and appendicular FM (in kg)
158 significantly decreased along the one year follow-up in the GBP group whereas it
159 significantly decreased until T6 and then stabilized from T6 to T12 in the SG group (Figure
160 1). As a result, body composition significantly improved as demonstrated by changes in the
161 percentage of FFM and FM (Table 1). GBP induced a significant improvement of obesity-
162 related comorbidities (except for high blood pressure (HBP)), whereas SG only led to a
163 significant improvement of dyslipidemia at T6 and T12 (Table 1).

165 **Food and macronutrient intakes**

166 At baseline, no difference was observed for energy, food or macronutrient intakes
167 between the two groups (Table 2). The BMR values revealed that patients from both groups
168 underreported their caloric intake by 8%.

169 After both GBP and SG, energy intake drastically decreased at T3 and slightly
170 increased at T12, although not reaching baseline intake levels (significant at all time points,
171 Table 2). These changes in energy intake were explained by a significant decrease in food
172 intake at T3 in the two surgical groups (non-significant for dairy products) and a tendency for
173 a modest increase in food intake at T12 (significant for starchy foods in the SG group, Table
174 2). Total protein intake drastically and significantly decreased at T3 in both groups, and a

175 majority of patients reported protein intake below the recommended value of 60 g/day (85.7%
176 after GBP and 79% after SG, Table 2). Afterwards, total protein intake slightly but
177 significantly increased at T12, although it remained below the baseline levels (Table 2).
178 Furthermore, 61% of the patients reported low dietary protein intake (64% and 58%
179 respectively for GBP and SG groups, Table 2) at T12. No significant changes in
180 macronutrient distribution (total fat, SFA, PUFA and total carbohydrates) were observed
181 during the follow-up in the two groups (T3 and T12, Table 2). Energy, food and
182 macronutrient intakes were not different between the two groups during the follow-up (T3
183 and T12, Table 2).

184

185 **Nutrient adequacy of the diet**

186 At baseline, neither the PANDiet scores nor the probabilities of nutrient adequacy
187 differed between the two groups (Table 3). Low probabilities of adequacy for protein were
188 observed in both groups compared to the French adult population [30].

189 After both BS, the percentage of patients taking the prescribed systematic
190 multivitamin and mineral supplements significantly increased, from baseline to T3: 14%
191 versus 77% for GBP and 10% vs. 76.7% for SG, as expected from the recommendations
192 (Table 3). This high adherence was maintained at T12 with 86% and 68% respectively for
193 GBP and SG (Table 3). Due to the supplementation, the global nutrient adequacy of the diet
194 did not drop and rather stabilized along the follow-up (PANDiet score and Adequacy sub-
195 score were not significantly different at all time points) and the probability of adequacy for
196 vitamin D was improved (Table 3). Of note, when the global nutrient adequacy of the diet was
197 calculated without taking into account the prescribed supplementation, we found that it
198 drastically decreased at T3 and barely increased at T12 (Supplemental Table 1). However,
199 since the prescribed supplementation neither contains protein, fiber nor phosphorus, lower

200 probabilities of adequacy for these nutrients were observed in both groups at T3 compared to
201 baseline (Table 3). Furthermore, although the probabilities of adequacy for these four
202 nutrients significantly increased at T12 in both groups compared to T3 due to the slight
203 increase in food intake, they remained below the baseline values (except for protein in the
204 GBP group, Table 3).

206 **Nutritional deficiencies**

207 At baseline, none of the metabolic and nutritional parameters were different between
208 the two groups (Table 4). As expected in severe obesity, 100% and 83% of the patients from
209 the GBP and SG groups, respectively, presented 25(OH)-vitamin-D3 deficiency as seen by
210 serum concentrations below 30 ng/ml (Table 4) with subsequent secondary
211 hyperparathyroidism in 50% of the subjects, showing major deficiency in this population.

212 After both BS, prealbumin concentration drastically and significantly decreased at T3
213 and further stabilized at T6 and T12 (Table 4). At T12, 38% of GBP patients and 52% of SG
214 patients presented mild protein depletion as shown by prealbumin concentration below the
215 normal range of 0.2 g/l and 21% of GBP patients and 16% of SG patients presented risk of
216 mild protein malnutrition as shown by albumin concentration below the normal value of 37
217 g/l (Table 4). Of note, two patients in the GBP group and one patient in the SG group
218 presented both mild protein depletion and risk of mild protein malnutrition (reviewer #1,
219 comments #5,6&7). After both BS, vitamin D supplementation enabled a significant increase
220 in 25(OH)-vitamin-D3 serum concentrations at T6, which stabilized at T12 (Table 4).
221 However, 50% and 21% of GBP and SG patients, respectively, still displayed secondary
222 hyperparathyroidism at T12 (Table 4). Since all patients were prescribed multivitamin and
223 mineral supplementation, we verified whether this supplementation might induce serum
224 concentrations of selected vitamins and minerals above the normal range at T12. In fact, there

225 were only a few such cases in the overall cohort: one with elevated serum thiamin (700
226 nmol/l) and one with high serum ferritin (740 µg/l) in the SG group, and one with elevated
227 vitamin B12 (580 pmol/l) in the GBP group. Importantly, all such elevations remained below
228 toxic levels.

230 **DISCUSSION**

231 To the best of our knowledge, this is the first study to assess the relationship between
232 food intake, nutrient adequacy of the diet and nutritional biological parameters systematically
233 measured before, three and twelve months after GBP and SG. In this study where the patients
234 had similar clinical characteristics at baseline (except for T2D prevalence), our main findings
235 are: (i) protein intake significantly decreases after both GBP and SG, inducing mild protein
236 depletion in more than a third of the patients one year after both surgical techniques (reviewer
237 #1, comments #5,6&7); (ii) even though patients after GBP experienced greater weight loss
238 than after SG, both types of surgery induced similar food restriction effects on the nutritional
239 adequacy of the diet and, (iii) systematic multivitamin and mineral supplementation after SG
240 seems to prevent these nutritional deficiencies, the same way as in GBP in the first year.

241 After one year, we observed that GBP led to significantly greater weight loss
242 compared to SG, in accordance with previous data from the literature, including a large
243 multicenter study [33,34]. Nevertheless, some controversy remains. Indeed other reports show
244 that changes in body weight were similar one year after both GBP and SG [15,19,35],
245 although these were smaller cohorts. We evaluated the evolution of body composition and
246 observed that, in both surgeries, total FFM decreased until three months and then stabilized,
247 whereas total FM displayed a continuous decrease during the follow-up. Our results are
248 consistent with previous reports showing changes in body composition following GBP [22] or
249 SG [36] as measured by DXA. Our results are also concordant with the only study comparing

250 these outcomes after both sleeve and by-pass [19]. In that study, the continuous weight loss
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2 251 during one year was due to the decrease of total FM, the total FFM being spared after four
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4 252 months [19]. More importantly, we observed that appendicular FFM decreased until three
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7 253 months and then stabilized, whereas appendicular FM continued to decrease throughout the
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10 254 follow-up period in both models. Appendicular FFM represents a better surrogate of muscle
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12 255 mass than total FFM [37], and this is the first time that this outcome and its evolution have
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14 256 been studied after SG. Interestingly, the change in appendicular FFM was similar in the two
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17 257 surgical procedures.

19 258 After both BS, we observed that 61% of the patients reported daily protein
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22 259 consumption under the recommended value of 60 g/day at T12 (64% for GBP and 58% for
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24 260 SG). Our results are consistent with those of Andreu *et al.* and Moizé *et al.* who found that
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27 261 respectively 37% and 46% of patients had a daily protein intake below 60 g/day one year after
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29 262 BS [19,38]. In accordance with those findings, we did not find any difference between GBP
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32 263 and SG [38]. We report a prevalence of insufficient protein intake that is nearly 2-fold higher
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34 264 than that reported by Moizé *et al.* (61% versus 37%), which is mostly attributable to the
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36 265 systematic protein supplementation prescribed by these authors to all of their patients [38].
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39 266 One objective of recommending a minimal protein intake of 60 g/day after both GBP and SG
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41 267 is to mitigate post-surgical FFM loss in the first months [17]. Indeed, Moizé *et al.*
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44 268 demonstrated that patients with insufficient protein intake during the follow-up lost more
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46 269 FFM in both SG and GBP than patients with sufficient protein intake [19]. Because skeletal
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49 270 muscle is the primary site of insulin-stimulated glucose disposal during euglycemia [39], loss
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51 271 of FFM might contribute to the development of insulin resistance and should be avoided in
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54 272 order to maintain the beneficial metabolic outcomes. An important goal of future long-term
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56 273 follow-up studies will be to determine whether insufficient protein intake following BS might

274 result in loss of muscular strength. Furthermore, longer-term weight stabilization (and regain)
275 should also be assessed in link with the quantity of protein intake.

276 After both BS, we also observed that prealbumin concentration significantly
277 decreased, resulting in more than a third of patients exhibiting mild protein depletion
278 (reviewer #1, comments #5,6&7). Our results are in line with the few studies that reported
279 changes in prealbumin concentration after GBP or SG. All studies found lower values at T12
280 after GBP compared to baseline [15,40,41]. Results with SG are more heterogeneous, with
281 reports showing both lower [42] or no change in prealbumin concentrations [15,41]. Of note,
282 Moizé *et al.* reported that 14% of GBP and 16% of SG patients experienced abnormalities in
283 prealbumin concentrations at T12 after BS [14]. As mentioned above, this difference may be
284 due to the systematic prescription of protein supplement in the Hospital Clinic of Barcelona
285 [19,38]. Adequate protein intake after BS is of utmost importance to prevent the patients from
286 experiencing hair loss, poor wound healing and adverse effects such as infections after skin
287 repair surgery and ultimately – but rarely – protein-calorie malnutrition [43,44] (reviewer #1,
288 comments #5,6&7).

289 Although SG merely restricts the volume of the stomach without intestinal
290 malabsorption [5], it also leads to an accelerated gastric emptying (reviewer #2, comment #4).
291 Subsequently faster gastrointestinal passage might promote nutrient deficiencies [45], as
292 observed in a recent study with increased faecal excretion of fatty acids [46], resulting in a
293 state of moderate malabsorption. Furthermore, SG decreases gastric intrinsic factor and
294 gastric acid production, two factors involved in vitamin B-12 and iron absorption. Because
295 most of our patients took the prescribed daily multivitamin and mineral supplements one year
296 after both GBP and SG, few patients experienced nutritional abnormalities (except for
297 25(OH)-vitamin-D3) and there was no difference between the two surgical groups. Our
298 results were consistent with previous data from the literature [14,15]. Conversely, others

299 reported a higher risk of vitamin B-12 and 25(OH)-vitamin-D3 deficiencies after GBP
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2 300 compared to SG [12]. It should be noted that in these three studies, patients undergoing GBP
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4 301 or SG were instructed to take multivitamin and mineral supplements on a daily basis after BS.
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7 302 Another point to take into account, is the risk of developing undesirably high levels of
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9 303 micronutrient concentrations due to the systematic supplementation as was previously
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11 304 reported after SG [7,8,11]. Herein, we only identified one patient with serum thiamin and
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13 305 another with serum ferritin above normal range. Nevertheless, it should be noted that the risk
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15 306 of excessive levels in those studies were mostly observed for vitamin A and B-6, which we
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17 307 did not assess. Altogether, these data highlight the importance to prescribe daily multivitamin
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19 308 and mineral supplements after both GBP and SG at least in the first year, but also to monitor
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21 309 the adherence of the patients to their supplementation.
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26 310 At baseline, the higher prevalence of glucose intolerance in patients undergoing GBP
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28 311 reflects the process of selection for different BS techniques, where GBP is the first choice for
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30 312 patients with T2D or glucose intolerance since it demonstrated its superiority over SG to
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32 313 improve glycemic status post-surgery [35]. We also observed that neither GBP nor SG
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34 314 enabled a significant improvement of HBP in terms of overall prevalence. Nevertheless, both
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36 315 the number of patients treated and the number of treatments per patients tended to decrease
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38 316 after both surgeries, suggesting slight improvement of HBP in this cohort of obese patients
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40 317 with many comorbidities. Nevertheless our data are in accordance with previous studies,
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42 318 which indicated that HBP may not be the best resolved comorbidity after surgery [47,48]
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44 319 (reviewer #1, comment #4).
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51 320 One of the main strengths of our study is the use of a validated web-based method of
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53 321 dietary assessment which allowed us to provide detailed quantification of the food and
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55 322 nutrient intake for each patient [24]. This method allows us to assess the use of multivitamin
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57 323 and mineral supplements and measure adherence of the patients to the supplementation.
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324 Although the interventions were not randomized in our study, our participants had
325 comparable clinical characteristics at baseline (except for T2D) and were provided the same
326 systematic supplementation regardless of the surgical procedure. The main limitation
327 concerns the relative small number of patients, especially in the group who completed the one
328 year follow-up (reviewer #1, comment #1). This may have prevented us from detecting
329 changes between FFM loss and low protein intake after both procedures. Future studies with
330 longer follow-up periods and larger sample size are needed to determine how poor dietary
331 habits and nutritional deficiencies correlate with weight maintenance at longer term and with
332 the improvement or resolution of obesity related co-morbidities. We intend to follow this
333 cohort in the second year of their surgery to assess their evolution in terms of nutritional risks
334 and body composition (reviewer #2, comment #7).

335 In conclusion, we observed similar food restriction effects on the nutritional adequacy
336 of the diet in the first year post GBP and SG surgery. We also observed comparable
337 consequences in terms of bioclinical evolution and micronutrient serum concentrations.
338 Altogether, our results advocate for a cautious monitoring of protein intake and a systematic
339 multivitamin and mineral supplementation after both GPB and SG – at least in the first year
340 for SG.

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342 **Conflict of interest.** The authors declare that they have no conflict of interest.

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TABLES

TABLE 1. Anthropometric parameters and clinical characteristics according the surgical models at baseline, 3 months, 6 months and 12 months¹.

	GBP				SG			
	Baseline n=22	3 months n=22	6 months n=22	12 months n=14	Baseline n=30	3 months n=30	6 months n=30	12 months n=19
Age, years	43.5 (38.0-51.0)	/	/	/	41.0 (36.0-49.0)	/	/	/
Sex (% female)	68.2	/	/	/	66.7	/	/	/
Anthropometric parameters								
Weight, kg	127 (113-139) ^d	101 (94-115) ^c	89 (83-106) ^b	83 (79-92) ^a	117 (108-137) ^d	98 (90-116) ^c	94 (81-111) ^b	103 (84-109) ^a
BMI, kg/m ²	45.5 (41.6-49.1) ^d	37.0 (33.6-42.0) ^c	33.5 (31.3-37.2) ^b	30.6 (27.8-33.6) ^a	43.2 (39.0-47.7) ^d	35.5 (32.8-41.7) ^c	35.6 (29.9-40.9) ^b	38.5 (29.2-41.1) ^a
Weight loss, kg	0.0 (0.0-0.0) ^a	23.2 (19.8-27.2) ^b	32.4 (28.0-38.4) ^c	38.8 (29.0-48.6) ^d	0.0 (0.0-0.0) ^a	18.3 (15.4-22.9) ^b	23.9 (18.7-29.9) ^{*c}	27.2 (25.6-33.0) ^{*d}
Fat free mass (%)	51.8 ^a	53.9 ^b	57.7 ^c	59.9 ^d	50.9 ^a	53.1 ^b	56.3 ^c	54.9 ^c
Fat mass (%)	45.8 ^d	43.2 ^c	39.4 ^b	36.9 ^a	46.6 ^c	44.0 ^b	40.7 ^a	42.2 ^a
Obesity related-diseases								
Type-2 diabetes, N (%)	12 (54) ^b	4 (18) ^a	4 (18) ^a	3 (21) ^a	10 (33)	7 (23)	7 (23)	3 (16)
Glucose intolerance, N (%)	16 (73) ^b	4 (18) ^a	4 (18) ^a	3 (21) ^{ab}	10 (33) [*]	7 (23)	7 (23)	3 (16)
OSA, N (%)	14 (64) ^b	13 (59) ^b	10 (45) ^b	3 (21) ^a	15 (50)	14 (48)	8 (27)	7 (37)
Dyslipidemia, N (%)	20 (91) ^b	18 (81) ^b	17 (77) ^b	5 (36) ^a	26 (87) ^b	21 (72) ^b	13 (43) ^a	6 (32) ^a
HBP, N (%)	12 (54)	11 (50)	8 (36)	5 (36)	9 (30)	9 (30)	9 (30)	7 (37)
Treatment for HBP, N (mean number of treatment) (reviewer #1, comment #4)	12 (2.1)	/	7 (1.6)	5 (1.6)	9 (2.8)	/	9 (1.9)	6 (2.0)

¹Labeled medians or percentages without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction or paired McNemar test. *Represents significant differences between GBP and SG. *Glucose intolerance is defined as either fasting hyperglycemia (1g/l ≤G< 1.26g/l) or 6%≤HbA1c<6.5%); dyslipidemia is defined as a patient with treatment (statin or fibrate) or hypertriglyceridemia ≥1.5g/l or hypoHDL<0.5g/l for women and hypoHDL<0.4g/l for men; High blood pressure*

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(HBP) is defined as a systolic blood pressure >140 mmHg and/or a diastolic blood pressure > 90mmHg or patients with an anti-hypertensive treatment; obstructive sleep apnea (OSA) is defined as an Index Apnea Hypopnea >5/hour with or without treatment.)

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TABLE 2. Energy, food and macronutrient intakes according to the surgical models at baseline, 3 months and 12 months¹.

	GBP			SG		
	Baseline n=22	3 months n=22	12 months n=14	Baseline n=30	3 months n=30	12 months n=19
Energy and food intakes						
Energy intake, <i>kcal/d</i>	2005 (1539-2266) ^c	711 (615-1006) ^a	1226 (8133-1559) ^b	1658 (1445-2395) ^c	833 (539-1108) ^a	1078 (793-1354) ^b
BMR, <i>kcal/d</i>	2179 (2005-2409) ^c	1770 (1702-2072) ^b	1653 (1480-1791) ^a	1959 (1853-2218) ^c	1742 (1593-1894) ^b	1686 (1565-1963) ^a
Fruit and vegetables, <i>serving/d</i>	4.8 (3.2-7.0) ^b	2.2 (0.8-3.2) ^a	2.1 (1.5-3.9) ^{ab}	3.0 (1.6-4.3) ^b	1.5 (0.8-2.1) ^a	1.4 (1.0-2.6) ^{ab}
Starchy foods, <i>serving/d</i>	2.8 (2.1-3.7) ^b	0.7 (0.3-1.2) ^a	1.1 (0.8-1.6) ^a	2.6 (2.1-3.3) ^c	0.7 (0.3-1.1) ^a	1.2 (0.7-1.7) ^b
Dairy products, <i>serving/d</i>	2.1 (1.3-3.1)	1.7 (0.5-2.6)	2.1 (0.8-2.5)	1.6 (1.0-2.4)	1.4 (0.6-1.9)	1.2 (0.7-1.7)
Meat and fish, <i>serving/d</i>	1.4 (1.0-2.6) ^b	0.8 (0.6-1.1) ^a	0.7 (0.4-1.6) ^{ab}	1.6 (1.1-2.5) ^b	0.9 (0.6-1.4) ^a	1.0 (0.7-1.8) ^{ab}
Macronutrient intakes						
Protein, <i>g/d</i>	83.5 (70.6-105.6) ^c	41.7 (24.0-49.0) ^a	50.4 (36.9-65.2) ^b	78.3 (64.0-107.2) ^c	41.2 (26.8-52.6) ^a	51.8 (36.4-65.3) ^b
N (%) < 60g/d	2 (9) ^a	19 (86) ^b	9 (64) ^b	4 (13) ^a	26 (87) ^b	11 (58) ^b
Protein, <i>g/kg/d</i>	0.66 (0.57-0.73) ^b	0.38 (0.24-0.46) ^a	0.59 (0.48-0.715) ^b	0.65 (0.57-0.80) ^c	0.39 (0.29-0.50) ^a	0.46 (0.39-0.74) ^b
Total Lipid, % <i>EI/d</i>	32.0 (30.0-40.6)	36.8 (32.4-39.3)	38.8 (33.6-45.6)	37.4 (33.2-39.9)	41.6 (35.8-44.7)	39.5 (37.1-44.5)
SFA, % <i>EI/d</i>	14.7 (11.3-16.4)	15.5 (13.1-16.6)	17.4 (13.7-20.9)	15.6 (14.5-18.7)	17.4 (15.3-19.6)	15.8 (13.7-19.4)
PUFA, % <i>EI/d</i>	4.8 (4.2-5.8)	4.3 (3.2-6.4)	3.5 (3.0-5.5)	5.0 (4.0-5.9)	5.0 (3.3-6.4)	5.6 (4.3-8.0)
Total Carbohydrate, % <i>EI/d</i>	47.8 (42.0-49.7)	44.0 (38.9-49.2)	42.2 (35.4-47.1)	44.1 (40.0-46.7)	37.4 (32.3-46.8)	42.4 (33.4-45.1)

¹Labeled medians or percentages without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction or paired McNemar test.

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TABLE 3. Multivitamin and mineral supplementation, PANDiet scores and probabilities of nutrient adequacy according to the surgical models at baseline, 3 months and 12 months¹

	GBP			SG		
	Baseline n=22	3 months n=22	12 months n=14	Baseline n=30	3 months n=30	12 months n=19
Supplementation, N (%)	3 (14) ^a	17 (77) ^b	12 (86) ^b	3 (10) ^a	23 (77) ^b	13 (68) ^b
PANDiet	67.4 (60.7-70.7)	74.7(61.5-76.3)	71.0 (65.3-75.0)	57.7 (54.0-63.1)	65.3 (57.2-71.3)	65.0 (57.4-73.0)
Moderation Sub-score	64.6 (58.6-85.6)	82.1 (75.6-85.3)	74.3 (61.8-81.2)	63.2 (51.3-73.5) ^a	70.9 (63.83-80.0) ^b	73.1 (66.7-78.1) ^b
Protein	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
Total Carbohydrate	1.00 (1.00-1.00)	1.00 (0.97-1.00)	1.00 (0.98-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
Total Fat	0.99 (.035-1.00)	0.81 (0.58-0.93)	0.59 (0.05-0.95)	0.84 (0.52-0.96)	0.42 (0.02-0.84)	0.57 (0.05-0.89)
SFA	0.19 (0.04-0.61)	0.12 (0.02-0.35)	0.02 (0.00-0.29)	0.05 (0.00-0.30)	0.02 (0.00-0.15)	0.10 (0.00-0.28)
Cholesterol	0.66 (0.36-0.99) ^a	0.99 (0.94-1.00) ^b	0.95 (0.51-0.99) ^{ab}	0.41 (0.15-0.79) ^a	0.98 (0.65-1.00) ^b	1.00 (0.65-1.00) ^b
Sodium	0.43 (0.18-0.77) ^a	1.00 (0.96-1.00) ^c	0.97 (0.71-1.00) ^b	0.51 (0.01-0.78) ^a	1.00 (0.97-1.00) ^b	0.99 (0.70-1.00) ^b
Adequacy Sub-score	63.7 (53.3-76.6)	69.4 (62.7-70.7)	73.2 (66.3-75.6)	51.6 (39.3-69.0)	63.1 (42.1-72.1)	63.2 (38.1-74.3)
Protein	0.51 (0.18-0.78) ^b	0.00 (0.00-0.03) ^a	0.30 (0.05-0.71) ^b	0.47 (0.17-0.81) ^c	0.00 (0.00-0.08) ^a	0.05 (0.00-0.68) ^b
Total Carbohydrate	0.86 (0.20-0.98)	0.43 (0.04-0.82)	0.20 (0.01-0.62)	0.44 (0.03-0.68)	0.09 (0.00-0.75)	0.24 (0.00-0.52)
Total Fat	0.69 (0.50-1.00)	0.93 (0.70-0.99)	1.00 (0.85-1.00)	1.00 (0.82-1.00)	0.99 (0.84-1.00)	1.00 (0.93-1.00)
PUFA	0.44 (0.25-0.80)	0.35 (0.07-0.73)	0.14 (0.02-0.60)	0.49 (0.21-0.76)	0.49 (0.07-0.83)	0.66 (0.24-0.91)
Fibre	0.19 (0.02-0.54) ^c	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^b	0.02 (0.00-0.06) ^c	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^b
Vitamin A	0.78 (0.35-0.94)	1.00 (0.74-1.00)	1.00 (1.00-1.00)	0.67 (0.44-0.96)	0.99 (0.53-1.00)	0.67 (0.01-1.00)
Thiamin	0.85 (0.48-0.98)	1.00 (0.90-1.00)	1.00 (1.00-1.00)	0.61 (0.34-0.81)	1.00 (0.40-1.00)	0.97 (0.05-1.00)
Riboflavin	0.96 (0.81-0.98)	1.00 (0.91-1.00)	1.00 (1.00-1.00)	0.83 (0.57-0.93)	1.00 (0.65-1.00)	0.97 (0.41-1.00)
Niacin	0.99 (0.76-1.00)	1.00 (0.99-1.00)	1.00 (1.00-1.00)	0.93 (0.85-0.99)	1.00 (0.89-1.00)	1.00 (0.65-1.00)
Vitamin B-6	0.81 (0.54-0.99)	1.00 (0.77-1.00)	1.00 (1.00-1.00)	0.44 (0.11-0.96)	1.00 (0.17-1.00)	0.98 (0.04-1.00)
Folate	0.85 (0.32-0.97)	0.94 (0.58-1.00)	0.98 (0.94-1.00)	0.56 (0.30-0.81)	0.86 (0.42-0.99)	0.86 (0.02-1.00)
Vitamin B-12	0.88 (0.75-0.98)	0.81 (0.42-0.96)	0.94 (0.84-1.00)	0.87 (0.76-0.97)	0.91 (0.77-0.99)	0.83 (0.66-1.00)

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Vitamin C	0.75 (0.25-0.95)	1.00 (0.64-1.00)	1.00 (1.00-1.00)	0.26 (0.00-0.82) ^a	1.00 (0.56-1.00) ^b	0.94 (0.06-1.00) ^{ab}
Vitamin D	0.01 (0.00-0.20) ^a	0.99 (0.50-1.00) ^b	1.00 (0.97-1.00) ^b	0.02 (0.00-0.58) ^a	0.96 (0.17-1.00) ^b	0.71 (0.31-0.99) ^b
Vitamin E	0.34 (0.11-0.94)	0.97 (0.46-1.00)	1.00 (0.95-1.00)	0.18 (0.02-0.44)	0.95 (0.03-0.99)	0.71 (0.17-1.00)
Calcium	0.87 (0.70-0.97)	1.00 (0.93-1.00)	1.00 (0.98-1.00)	0.82 (0.43-0.97)	0.85 (0.02-1.00)	0.44 (0.04-1.00)
Magnesium	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)
Zinc	0.75 (0.37-0.94)	1.00 (0.86-1.00)	1.00 (1.00-1.00)	0.58 (0.27-0.86)	1.00 (0.15-1.00)	0.94 (0.13-1.00)
Phosphorus	1.00 (1.00-1.00) ^c	0.59 (0.03-0.96) ^a	0.90 (0.78-0.99) ^b	0.99 (0.96-1.00) ^c	0.60 (0.04-0.87) ^a	0.86 (0.14-1.00) ^b
Potassium	0.69 (0.45-0.93) ^b	0.01 (0.00-0.29) ^a	0.01 (0.00-0.15) ^a	0.39 (0.14-0.89) ^c	0.00 (0.00-0.02) ^a	0.03 (0.00-0.12) ^b
Iron	0.93 (0.85-1.00)	1.00 (0.85-1.00)	1.00 (0.96-1.00)	0.93 (0.55-1.00)	1.00 (0.45-1.00)	0.85 (0.15-1.00)

¹Labeled medians or percentages without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction or paired McNemar test.

TABLE 4. Metabolic and nutritional parameters according the surgical models at baseline, 3 months, 6 months and 12 months¹

	GBP				SG			
	Baseline n=22	3 months n=22	6 months n=22	12 months n=14	Baseline n=30	3 months n=30	6 months n=30	12 months n=19
Hemoglobin (g/dl)	13.9 (13.0-14.7)	13.9 (13.4-14.7)	13.8 (13.5-14.1)	13.7 (13.3-14.1)	13.7 (13.2-14.5)	13.7 (12.9-14.4)	13.6 (13.1-14.1)	13.4 (13.0-14.1)
<12 g/dl N(%)	2 (9)	0 (0)	1 (5)	1 (7)	0 (0)	1 (3)	0 (0)	1 (5)
Ferritin (µg/l)	115 (62-201)	86 (69-188)	96 (65-199)	100 (58-166)	121 (39-230)	154 (92-266)	144 (92-234)	144 (82-176)
<30 µg/l N(%)	3 (14)	0 (0)	1 (5)	1 (7)	3 (10)	1 (3)	1 (3)	1 (5)
Iron (µmol/l)	14.0 (10.0-16.0)	13.0 (12.0-17.0)	15.0 (13.0-18.0)	15.0 (12.0-18.0)	15.0 (12.0-22.0)	16.0 (14.0-19.0)	17.0 (13.0-19.0)	16.5 (13.0-19.0)
<9 µmol/l N (%)	4 (18)	0 (0)	0 (0)	0 (0)	2 (7)	2 (7)	0 (0)	1 (5)
Transferrin (g/l)	3.1 (2.7-3.1)	2.3 (2.2-2.8)	2.4 (2.1-2.8)	2.5 (2.0-2.8)	2.7 (2.5-2.9)	2.4 (2.2-2.7)	2.5 (2.3-2.7)	2.6 (2.3-2.7)
>3.1 g/l N(%)	3 (14)	2 (9)	2 (9)	1 (7)	3 (10)	0 (0)	1 (3)	0 (0)
Total iron binding capacity (µmol/l)	67.5 (61.0-76.0)	58.0 (55.0-71.0)	59.0 (53.0-69.0)	62.0 (51.0-70.0)	66.5 (61.0-72.0)	61.0 (56.0-67.0)	62.0 (58.0-67.0)	64.0 (57.0-67.0)
>80 µmol/l N(%)	1 (5)	2 (9)	1 (5)	1 (7)	2 (7)	0 (0)	1 (3)	0 (0)
Transferrin saturation coefficient (%)	0.21 (0.16-0.26)	0.22 (0.17-0.24)	0.25 (0.19-0.32)	0.24 (0.19-0.33)	0.25 (0.18-0.33)	0.29 (0.23-0.33)	0.28 (0.20-0.32)	0.25 (0.23-0.29)
<0.15% N(%)	5 (23)	3 (14)	1 (5)	3 (21)	2 (7)	1 (3)	1 (3)	1 (5)
Albumin (g/l)	35.5 (33.0-37.0) ^a	39.0 (36.0-41.0) ^b	38.0 (36.0-41.0) ^b	39.0 (37.0-40.0) ^b	37.0 (35.0-39.0) ^a	40.0 (37.0-42.0) ^b	40.0 (38.0-42.0) ^b	41.0 (38.0-42.0) ^b
<37 g/l N(%)	13 (59)	7 (32)	6 (27)	3 (21)	14 (47)	6 (20)	2 (7)	3 (16)
Prealbumin (g/l)	0.25 (0.19-0.30) ^b	0.20 (0.16-0.21) ^a	0.20 (0.19-0.22) ^a	0.20 (0.18-0.0.25) ^{ab}	0.23 (0.21-0.25) ^b	0.18 (0.17-0.21) ^a	0.19 (0.18-0.21) ^a	0.19 (0.18-0.22) ^a
<0.2 g/L N(%)	6 (27)	8 (37)	10 (45)	5 (38)	5 (17) ^a	17 (57) ^b	15 (50) ^b	10 (52) ^b
Calcium (mmol/l)	2.29 (2.24-2.37)	2.39 (2.33-2.43)	2.37 (2.28-2.39)	2.31 (2.26-2.39)	2.31 (2.24-2.38)	2.37 (2.31-2.44)	2.31 (2.28-2.38)	2.33 (2.31-2.38)
25(OH)-vitamin-D3 (ng/ml)	13.0 (10.0-23.0) ^a	/	29.5 (26.5-32.0) ^b	27.0 (22.0-29.0) ^b	17.0 (11.0-23.0) ^a	/	26.9 (22.5-30.5) ^b	25.0 (20.0-30.0) ^b
<30 ng/ml N(%)	19 (86)	/	10 (45)	10 (71)	25 (83)	/	18 (60)	13 (68)
Parathyroid hormone (pg/ml)	48.3 (41.5-58.9)	/	/	44.1 (35.1-47.1)	46.8 (36.4-54.0)	/	/	39.5 (32.3-43.3)
>45 pg/ml N(%)	13 (59)	/	/	6 (43)	15 (50)	/	/	4 (21)
Thiamin (nmol/l)	157 (150-174)	/	193 (155-193)	197 (174-215)	147 (134-175)	/	177 (158-191)	181 (149-218)
<126 nmol/l N(%)	2 (9)	/	1 (5)	0 (0)	5 (17)	/	1 (3)	0 (0)

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Erythrocyte folate (nmol/l)	1287 (1023-1429) /	1760 (1457-1961)	1940 (1421-2169)	1234 (1036-1377) ^a /	1411 (1246-1806) ^b	1540 (1366-1804) ^b
<945 nmol/l N(%)	4 (18) /	2 (9)	0 (0)	5 (17) /	0 (0)	0 (0)
Serum folate (nmol/l)	16.8 (12.9-24.0) /	26.9 (22.8-33.4)	27.9 (22.8-41.0)	17.7 (14.7-20.5) ^a /	22.8 (18.4-28.4) ^b	20.2 (15.6-26.4) ^b
Vitamin B-12 (pmol/l)	284 (209-334) /	252 (227-345)	221 (195-278)	293 (248-358) /	311 (224-464)	311 (216-432)
<140 pmol/l N(%)	1 (5) /	1 (5)	0 (0)	1 (3) /	0 (0)	0 (0)

¹Labeled medians or percentages without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction or paired McNemar test. *Normal ranges are as follows: hemoglobin [12-17] g/dl; ferritin [30-300] µg/l; iron [9-27] µmol/l; transferrin [1.7-3.1] g/l; total iron binding capacity [40-80] µmol/l; transferrin saturation coefficient [0.15-0.35] %; albumin [37-50] g/l; prealbumin [0.2-0.35] g/l; calcium [2.1-2.65] mmol/l; 25(OH)-vitamin-D3 [30-100] ng/ml; thiamin [126-250] nmol/l; serum folate [7-39.5] nmol/l, vitamin B-12 [140-490] pmol/l.*

FIGURE LEGENDS

FIGURE 1. Changes in body composition in the GBP and SG groups at baseline (T0) and along the follow-up (T3, T6 and T12).

Results are expressed as means \pm SDs. Evolution of body composition during follow-up. Gastric sleeve in grey and GBP in black; top left panel fat free mass; top right panel total fat mass, low left panel appendicular fat free mass (i.e. arms + legs), low right panel appendicular fat mass. Labeled means without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction. No significant difference between GBP and SG was observed.

SUPPLEMENTAL DATA

SUPPLEMENTAL TABLE 1. PANDiet scores and probabilities of nutrient adequacy according to the surgical models at baseline, 3 months and 12 months (calculated from foods only)¹

	GBP			SG		
	Baseline n=22	3 months n=22	12 months n=14	Baseline n=30	3 months n=30	12 months n=19
PANDiet	66.0 (60.7-70.5) ^b	51.6 (47.8-53.7) ^a	52.1 (46.1-57.6) ^a	57.7 (54.0-62.1) ^b	47.6 (40.9-53.0) ^a	52.9 (46.7-60.6) ^b
Moderation Sub-score	64.6 (58.6-85.6)	82.1 (75.6-85.3)	74.3 (61.8-81.2)	63.2 (51.3-73.5) ^a	70.9 (63.8-80.0) ^b	73.1 (66.7-78.1) ^b
Protein	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
Total Carbohydrate	1.00 (1.00-1.00)	1.00 (0.97-1.00)	1.00 (0.98-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
Total Fat	0.99 (0.93-1.00)	0.81 (0.58-0.93)	0.59 (0.05-0.95)	0.84 (0.52-0.96)	0.42 (0.02-0.84)	0.57 (0.05-0.89)
SFA	0.19 (0.04-0.61)	0.12 (0.02-0.35)	0.02 (0.00-0.29)	0.05 (0.00-0.30)	0.02 (0.00-0.15)	0.10 (0.00-0.28)
Cholesterol	0.66 (0.36-0.99) ^a	0.99 (0.94-1.00) ^b	0.95 (0.51-0.99) ^{ab}	0.41 (0.15-0.79) ^a	0.98 (0.65-1.00) ^b	1.00 (0.65-1.00) ^b
Sodium	0.43 (0.18-0.77) ^a	1.00 (0.96-1.00) ^c	0.97 (0.71-1.00) ^b	0.51 (0.01-0.78) ^a	1.00 (0.97-1.00) ^b	0.99 (0.70-1.00) ^b
Adequacy Sub-score	60.8 (53.0-72.0) ^b	22.1 (14.9-34.5) ^a	30.3 (22.8-42.8) ^a	51.6 (38.4-69.0) ^c	20.6 (11.9-35.2) ^a	27.0 (16.8-44.4) ^b
Protein	0.51 (0.18-0.78) ^b	0.00 (0.00-0.03) ^a	0.30 (0.05-0.71) ^b	0.47 (0.17-0.81) ^c	0.00 (0.00-0.08) ^a	0.05 (0.00-0.68) ^b
Total Carbohydrate	0.86 (0.20-0.98)	0.43 (0.04-0.82)	0.20 (0.01-0.62)	0.44 (0.03-0.68)	0.09 (0.00-0.75)	0.24 (0.00-0.52)
Total Fat	0.69 (0.50-1.00)	0.93 (0.70-0.99)	1.00 (0.85-1.00)	1.00 (0.82-1.00)	0.99 (0.84-1.00)	1.00 (0.93-1.00)
PUFA	0.44 (0.25-0.80)	0.35 (0.07-0.73)	0.14 (0.02-0.60)	0.49 (0.21-0.76)	0.49 (0.07-0.83)	0.66 (0.24-0.91)
Fibre	0.19 (0.02-0.54) ^c	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^b	0.02 (0.00-0.06) ^c	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^b
Vitamin A	0.71 (0.30-0.91) ^b	0.12 (0.00-0.51) ^a	0.43 (0.05-0.70) ^{ab}	0.67 (0.44-0.96) ^b	0.07 (0.00-0.61) ^a	0.16 (0.00-0.59) ^a
Thiamin	0.84 (0.48-0.97) ^b	0.01 (0.00-0.19) ^a	0.16 (0.01-0.42) ^a	0.56 (0.31-0.77) ^b	0.02 (0.00-0.32) ^a	0.01 (0.00-0.35) ^a
Riboflavin	0.89 (0.79-0.98) ^b	0.06 (0.01-0.67) ^a	0.12 (0.03-0.75) ^a	0.83 (0.57-0.93) ^b	0.21 (0.00-0.46) ^a	0.08 (0.00-0.70) ^a
Niacin	0.99 (0.76-1.00) ^b	0.09 (0.00-0.60) ^a	0.54 (0.10-0.82) ^a	0.93 (0.85-0.99) ^b	0.34 (0.00-0.84) ^a	0.68 (0.41-0.98) ^a
Vitamin B-6	0.81 (0.54-0.98) ^b	0.00 (0.00-0.04) ^a	0.00 (0.00-0.28) ^a	0.44 (0.11-0.96) ^b	0.00 (0.00-0.10) ^a	0.01 (0.00-0.08) ^a
Folate	0.83 (0.32-0.97) ^b	0.04 (0.01-0.17) ^a	0.08 (0.01-0.48) ^a	0.56 (0.30-0.81) ^b	0.03 (0.00-0.18) ^a	0.04 (0.01-0.16) ^a
Vitamin B-12	0.88 (0.75-0.98) ^b	0.31 (0.02-0.80) ^a	0.72 (0.38-0.90) ^b	0.87 (0.76-0.97) ^b	0.63 (0.12-0.83) ^a	0.73 (0.25-0.86) ^a

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Vitamin C	0.63 (0.20-0.95) ^b	0.05 (0.00-0.57) ^{ab}	0.09 (0.00-0.47) ^a	0.26 (0.00-0.82) ^b	0.00 (0.00-0.16) ^a	0.04 (0.00-0.21) ^{ab}
Vitamin D	0.00 (0.00-0.10) ^b	0.00 (0.00-0.00) ^a	0.00 (0.00-0.02) ^{ab}	0.02 (0.00-0.30)	0.00 (0.00-0.08)	0.15 (0.00-0.44)
Vitamin E	0.29 (0.08-0.89) ^c	0.00 (0.00-0.00) ^a	0.00 (0.00-0.03) ^b	0.18 (0.02-0.44) ^b	0.00 (0.00-0.01) ^a	0.13 (0.00-0.39) ^b
Calcium	0.87 (0.07-0.97) ^b	0.28 (0.00-0.77) ^a	0.49 (0.07-0.86) ^a	0.82 (0.43-0.97) ^b	0.06 (0.00-0.35) ^a	0.08 (0.00-0.56) ^a
Magnesium	0.00 (0.00-0.00) ^b	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^b	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^a
Zinc	0.72 (0.35-0.90) ^b	0.01 (0.00-0.14) ^a	0.03 (0.01-0.21) ^a	0.58 (0.27-0.86) ^c	0.01 (0.00-0.06) ^a	0.11 (0.00-0.51) ^b
Phosphorus	1.00 (1.00-1.00) ^c	0.59 (0.03-0.96) ^a	0.90 (0.78-0.99) ^b	0.99 (0.96-1.00) ^c	0.60 (0.04-0.87) ^a	0.86 (0.14-1.00) ^b
Potassium	0.69 (0.45-0.93) ^b	0.01 (0.00-0.29) ^a	0.01 (0.00-0.15) ^a	0.39 (0.14-0.89) ^c	0.00 (0.00-0.02) ^a	0.03 (0.00-0.12) ^b
Iron	0.85 (0.65-1.00) ^b	0.04 (0.00-0.55) ^a	0.25 (0.00-0.55) ^a	0.93 (0.55-1.00) ^b	0.10 (0.00-0.45) ^a	0.15 (0.00-0.85) ^a

¹Labeled medians without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction.

Micronutrient and protein deficiencies after gastric bypass and sleeve gastrectomy: a one-year follow-up

Original Contribution

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Running title: Malnutrition after surgery

Financial Support: This project is supported by the « Contrat de Recherche Clinique » from Health ministry (CRC Fibrota P100503 – IDRCB 2011-A00759-32, recorded on clinical trial website (NCT: NCT01655017), as well as by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement HEALTH-F4-2012-305312 (Metacardis) and the National Agency of Research (Investissement D'Avenir, ANR-10-IAHU-05). JAW received a grant from Institut Appert and from Nestlé research. The authors declare that they have no conflict of interest.

The authors wish to thank Ms Agathe Arlotti for the coordination of programs on bariatric surgery (BARICAN program), Ms Valentine Lemoine for her help in the follow-up of the patients and Dr Florence Marchelli who contributed to clinical and biological database constitution.

1 **ABSTRACT**

2 **Background:** Roux-en-Y gastric bypass (GBP) and sleeve gastrectomy (SG) have increased
3 dramatically, potentially increasing the prevalence of nutritional deficiencies. The aim of this
4 study was to analyze the effects of food restriction during the first year after bariatric surgery
5 (BS) on nutritional parameters.

6 **Methods:** 22 and 30 obese patients undergoing GBP and SG were prospectively followed at
7 baseline and three, six and twelve months after BS (N=14 and N=19 at T12). We evaluated
8 food intake and nutrient adequacy (T0, T3, T12), as well as serum vitamins and minerals
9 concentration (T0, T3, T6, T12).

10 **Results:** At baseline, GBP and SG patients had similar clinical characteristics, food intake,
11 nutrient adequacy and serum concentration. The drastic energy and food reduction led to very
12 low probabilities of adequacy for nutrients similar in both models (T3, T12). Serum analysis
13 demonstrated a continuous decrease in prealbumin during the follow-up, indicating mild
14 protein depletion in 37% and 38% of GBP patients and 57% and 52% of SG patients,
15 respectively at T3 and T12. Conversely, despite the low probabilities of adequacy observed at
16 T3 and T12, systematic multivitamin and mineral supplementation after GBP and SG
17 prevented most nutritional deficiencies.

18 **Conclusion:** GBP and SG have comparable effects in terms of energy and food restriction,
19 and subsequent risk of micronutrient and protein deficiencies in the first year post BS. Such
20 results advocate for a cautious monitoring of protein intake after GPB and SG and a
21 systematic multivitamin and mineral supplementation in the first year after SG.

22
23 **Keywords:** Bariatric surgery; Roux-en-Y Gastric Bypass; Sleeve gastrectomy; Protein
24 deficiency; Multivitamin and mineral supplementation.

26 INTRODUCTION

27 Among the few therapeutic tools to treat morbid obesity, bariatric surgery (BS)
28 appears to be the most effective strategy as demonstrated by its ability to obtain major and
29 sustainable weight loss along with significant improvement of obesity related-comorbidities
30 [1,2]. As a result, the number of interventions has dramatically risen worldwide, and Roux-
31 en-Y Gastric Bypass (GBP) and Sleeve Gastrectomy (SG) represented respectively 47% and
32 28% of the 340,000 BS performed in 2011 [3]. Since 2008, SG has emerged to such an extent
33 that it has become the most common procedure in several countries, as is the case in France
34 [3]. Although the two surgical techniques and their mechanisms of action differ, they appear
35 to be equally safe and both induce significant weight loss post-surgery [4].

36 GBP includes diet restriction as well as the bypass of the proximal part of the jejunum
37 involved in nutrient absorption whereas SG is less invasive and principally restricts the
38 volume of the stomach [5]. Therefore SG, compared to GBP, might be viewed as less likely to
39 exacerbate the risk of micronutrient deficiencies in obese patients who are already prone to
40 such deficiencies before surgery [6]. Nevertheless, some studies have demonstrated a
41 considerably higher prevalence of nutrient deficiencies after SG [7–11]. Others, comparing
42 GBP and SG, found quite similar prevalence after both procedures [12–16]. Although study
43 designs differed, these converging results highlight the importance of daily multivitamin and
44 mineral supplementation after both procedures, at least in the first year for SG, in accordance
45 with the latest US guidelines [17]. While the previously mentioned studies evaluated nutrient
46 deficiencies using serum biomarker concentrations, only very few have evaluated food and
47 nutrient intake after GBP and SG: Freeman *et al.* evaluated food intake two to four years after
48 surgery [18], Moizé *et al.* and Coupaye *et al.* evaluated the overall macronutrient intake
49 during one year after BS but did not quantify micronutrient intake [15,19], and Moizé *et al.*
50 evaluated macronutrient and some selected mineral intake during five years after BS [14].

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Therefore, we aimed to analyze food restriction effects on the nutritional adequacy of the diet, on macro and micronutrient intake evolution as well as their consequences in terms of bioclinical evolution and micronutrient serum level during one year after both GBP and SG.

56 **MATERIAL AND METHODS**

57 **Patients**

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Obese candidates for either GBP or SG according to the international bariatric surgery guidelines [20] (i.e. body mass index (BMI) $\geq 40 \text{ kg/m}^2$, or $\geq 35 \text{ kg/m}^2$ with at least one severe obesity-related comorbidity) were treated in the Obesity Unit of Pitié-Salpêtrière Hospital, Institute of Cardio-metabolism and Nutrition, ICAN, Paris, France. Patients determined the choice of technique, and advised by a multidisciplinary panel, from the hospital based on medical history, level of corpulence and obesity-related comorbidity. Weight stable patients were enrolled consecutively in this prospective non-randomized study from January 2012. Hotel-Dieu hospital ethics committee approved the clinical protocol (number P100503 – IDRCB 2011-A00759-32) which was recorded on clinical trial website (NCT: NCT01655017). Subjects gave their written informed consent prior to the study inclusion.

Medical history and clinical evaluation were obtained at baseline and during the follow-up at three (T3), six (T6) and twelve months (T12) as described elsewhere [21]. Anthropometric parameters were estimated by whole-body fan-beam DXA scanning (Hologic Discovery W, software v12.6, 2; Hologic, Bedford, MA), as previously described [22]. Variables from DXA used in the analyses were total and appendicular fat free mass (FFM, in kg), and total and appendicular fat mass (FM, in kg), where appendicular FFM (or FM) was calculated as the sum of FFM (or FM) from both arms and both legs. Basal metabolic rate

75 (BMR) was assessed with indirect calorimetry (Deltatrac II monitor, Datex Instrumentarium
76 Corp., Helsinki, Finland) enabling the evaluation of underreporting of dietary intake [23].

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78 **Dietary data and nutrient intakes**

79 At baseline, T3 and T12, patients completed three consecutive web-based 24h dietary
80 records as described elsewhere [24], including two weekdays and one day on the weekend
81 whenever possible. All foods and beverages consumed at breakfast, lunch, dinner and snacks
82 were recorded. Validated photographs enabled patients to estimate portion size for each
83 reported food and beverage item [25]. Patients were also asked to indicate multivitamin and
84 mineral supplements use, specifying the product name and amount, following the nutritional
85 deficiency prevention treatment prescribed for every patient at our center, as described in
86 [26]. This includes supplementation during two weeks before surgery of vitamin D (once
87 4×100,000 IU), thiamin (250 mg/day), and vitamin B-12 (250µg/day). Fifteen days post-GBP
88 and SG, multivitamin and mineral supplements including Azinc “Forme et vitalité”® (two
89 capsules per day, containing 800 µg vitamin A, 1.4mg thiamin, 200 µg folate, 1µg vitamin B-
90 12, 120 mg vitamin C, 200 IU vitamin D, 8 mg iron and 15 mg zinc), iron (2×80 mg/ day),
91 vitamin D (800 IU/day), and calcium (1,000mg/day) were started and continued for the first
92 year in both BS procedures. Intake of nutrients derived from food were calculated using an
93 updated version of the French database CIQUAL 2008 [27] which included more than 3,400
94 different food items. Nutrient intakes from multivitamin and mineral supplements were
95 calculated using nutrient profile based on the product name. Ingested foods were categorized
96 into 4 main food groups when possible: (i) fruit and vegetables, (ii) starchy foods, (iii) dairy
97 products, and (iv) meat and fish. The food groups were defined according to the French
98 National Nutrition and Health Program [28] and expressed in servings per day based on
99 standard serving sizes [29].

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2 **101 Nutrient adequacy of the diet**
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5 102 Nutrient intake adequacy for each patient was calculated using the PANDiet index
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7 103 [30]. Briefly, probability of adequacy for each nutrient was calculated, ranging from 0 to 1,
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9 104 where 1 represents a 100% probability that the usual intake is adequate (i.e. it satisfies the
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11 105 requirement or is not excessive compared to a reference value). According to this definition,
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13 106 the probabilities of adequacy were computed to obtain the Adequacy sub-score (the higher,
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15 107 the better the intake satisfies the nutrient requirements) and the Moderation sub-score (the
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17 108 higher, the less likely the intake is excessive). The PANDiet score is taken as the mean of the
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19 109 Adequacy and Moderation sub-scores, and ranges from 0 to 100; the higher the score, the
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21 110 better the nutrient adequacy of the diet. As reference values, we used French nutritional
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23 111 recommendations for healthy adults or European Union values when specific
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25 112 recommendations were lacking.
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34 **114 Biochemical analyses**
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36 115 Blood samples were collected after an overnight fast to measure biochemical
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38 116 parameters using routine techniques as described [31]. Blood count and iron metabolism
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40 117 markers (i.e. ferritin, iron, transferrin, and saturation coefficient) were assessed using routine
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42 118 care method (nephelemetry, ferrozine colorimetry and immunoturbidimetry respectively).
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44 119 Prealbumin was assessed by immunoturbidimetry. Serum concentrations of 25(OH)-vitamin-
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46 120 D3 and parathyroid hormone (PTH) were measured by chemiluminescent assay (310600
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48 121 Liaison XL Diasorin and 11972103 Modular E 170 Roche, respectively), vitamin B-12 and
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50 122 folate were assessed using immunoanalysis ECL sandwich, and thiamin and vitamin B-6 were
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52 123 assessed using HPLC [6]. Vitamin and mineral deficiencies were defined as a result below the
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54 124 lower normal value given by the manufacturer [32]. Secondary hyperparathyroidism was
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125 defined as an elevated PTH, above the high normal laboratory value. All measurements were
126 conducted at baseline, T3, T6 and T12 (except for 25(OH)-vitamin-D3, PTH, thiamin, folate
127 and vitamin B-12 at T3, and PTH at T6).

129 **Statistical analyses**

130 Continuous variables are presented as median and interquartile range (IQR) and
131 frequencies as percentages. Mann-Whitney and paired Wilcoxon rank-sum tests were,
132 respectively, used to compare continuous variables between surgical groups and time-points.
133 Chi-squared and McNemar tests were used to compare frequencies between surgical groups
134 and time-points, respectively. An overall α level of 5% was used for statistical tests following
135 Holm-Bonferroni correction. These analyses were conducted on both the patients who
136 completed T3 and T6, and on the patients who completed T3, T6 and T12. Since no
137 significant difference was observed between two groups of patients both at baseline, and
138 during the follow-up at T3 and T6, outcomes are merged when presented on tables and
139 figures. All analyses were performed using Statistical Analysis Systems statistical software
140 package version 9.3 (SAS Institute, Cary, NC, SA).

142 **RESULTS**

143 **Clinical characteristics**

144 Fifty-two patients were included in this study (22 GBP and 30 SG). All of them
145 completed the first six months follow-up of this study (T3 and T6), and 33 completed the one
146 year follow-up (T3, T6 and T12; 14 GBP and 19 SG). Importantly, the two groups were
147 similar at baseline regarding sex, age, corpulence and body composition (Table 1). Likewise,
148 the severity of obesity related-comorbidities was similar in the two groups, except for glucose
149 intolerance, which was significantly more prevalent in the GBP group (Table 1).

150 As expected, BS induced significant weight loss in both surgical techniques, however
151 GBP led to a significantly greater weight loss at T6 and T12 compared to SG (Table 1). More
152 specifically, the total and appendicular FFM (in kg) significantly decreased at T3 and then
153 stabilized at T6 and T12 in the two groups, while the total and appendicular FM (in kg)
154 significantly decreased along the one year follow-up in the GBP group whereas it
155 significantly decreased until T6 and then stabilized from T6 to T12 in the SG group (Figure
156 1). As a result, body composition significantly improved as demonstrated by changes in the
157 percentage of FFM and FM (Table 1). GBP induced a significant improvement of obesity-
158 related comorbidities (except for high blood pressure (HBP)), whereas SG only led to a
159 significant improvement of dyslipidemia at T6 and T12 (Table 1).

161 **Food and macronutrient intakes**

162 At baseline, no difference was observed for energy, food or macronutrient intakes
163 between the two groups (Table 2). The BMR values revealed that patients from both groups
164 underreported their caloric intake by 8%.

165 After both GBP and SG, energy intake drastically decreased at T3 and slightly
166 increased at T12, although not reaching baseline intake levels (significant at all time points,
167 Table 2). These changes in energy intake were explained by a significant decrease in food
168 intake at T3 in the two surgical groups (non-significant for dairy products) and a tendency for
169 a modest increase in food intake at T12 (significant for starchy foods in the SG group, Table
170 2). Total protein intake drastically and significantly decreased at T3 in both groups, and a
171 majority of patients reported protein intake below the recommended value of 60 g/day (85.7%
172 after GBP and 79% after SG, Table 2). Afterwards, total protein intake slightly but
173 significantly increased at T12, although it remained below the baseline levels (Table 2).
174 Furthermore, 61% of the patients reported low dietary protein intake (64% and 58%

175 respectively for GBP and SG groups, Table 2) at T12. No significant changes in
176 macronutrient distribution (total fat, SFA, PUFA and total carbohydrates) were observed
177 during the follow-up in the two groups (T3 and T12, Table 2). Energy, food and
178 macronutrient intakes were not different between the two groups during the follow-up (T3
179 and T12, Table 2).

181 **Nutrient adequacy of the diet**

182 At baseline, neither the PANDiet scores nor the probabilities of nutrient adequacy
183 differed between the two groups (Table 3). Low probabilities of adequacy for protein were
184 observed in both groups compared to the French adult population [30].

185 After both BS, the percentage of patients taking the prescribed systematic
186 multivitamin and mineral supplements significantly increased, from baseline to T3: 14%
187 versus 77% for GBP and 10% vs. 76.7% for SG, as expected from the recommendations
188 (Table 3). This high adherence was maintained at T12 with 86% and 68% respectively for
189 GBP and SG (Table 3). Due to the supplementation, the global nutrient adequacy of the diet
190 did not drop and rather stabilized along the follow-up (PANDiet score and Adequacy sub-
191 score were not significantly different at all time points) and the probability of adequacy for
192 vitamin D was improved (Table 3). Of note, when the global nutrient adequacy of the diet was
193 calculated without taking into account the prescribed supplementation, we found that it
194 drastically decreased at T3 and barely increased at T12 (Supplemental Table 1). However,
195 since the prescribed supplementation neither contains protein, fiber nor phosphorus, lower
196 probabilities of adequacy for these nutrients were observed in both groups at T3 compared to
197 baseline (Table 3). Furthermore, although the probabilities of adequacy for these four
198 nutrients significantly increased at T12 in both groups compared to T3 due to the slight

199 increase in food intake, they remained below the baseline values (except for protein in the
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2 200 GBP group, Table 3).

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7 202 **Nutritional deficiencies**

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9 203 At baseline, none of the metabolic and nutritional parameters were different between
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12 204 the two groups (Table 4). As expected in severe obesity, 100% and 83% of the patients from
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14 205 the GBP and SG groups, respectively, presented 25(OH)-vitamin-D3 deficiency as seen by
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16 206 serum concentrations below 30 ng/ml (Table 4) with subsequent secondary
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19 207 hyperparathyroidism in 50% of the subjects, showing major deficiency in this population.
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22 208 After both BS, prealbumin concentration drastically and significantly decreased at T3
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24 209 and further stabilized at T6 and T12 (Table 4). At T12, 38% of GBP patients and 52% of SG
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26 210 patients presented mild protein depletion as shown by prealbumin concentration below the
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29 211 normal range of 0.2 g/l and 21% of GBP patients and 16% of SG patients presented risk of
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31 212 mild protein malnutrition as shown by albumin concentration below the normal value of 37
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34 213 g/l (Table 4). Of note, two patients in the GBP group and one patient in the SG group
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36 214 presented both mild protein depletion and risk of mild protein malnutrition. After both BS,
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39 215 vitamin D supplementation enabled a significant increase in 25(OH)-vitamin-D3 serum
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41 216 concentrations at T6, which stabilized at T12 (Table 4). However, 50% and 21% of GBP and
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44 217 SG patients, respectively, still displayed secondary hyperparathyroidism at T12 (Table 4).
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46 218 Since all patients were prescribed multivitamin and mineral supplementation, we verified
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49 219 whether this supplementation might induce serum concentrations of selected vitamins and
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51 220 minerals above the normal range at T12. In fact, there were only a few such cases in the
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54 221 overall cohort: one with elevated serum thiamin (700 nmol/l) and one with high serum ferritin
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56 222 (740 µg/l) in the SG group, and one with elevated vitamin B12 (580 pmol/l) in the GBP
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58 223 group. Importantly, all such elevations remained below toxic levels.
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225 **DISCUSSION**

226 To the best of our knowledge, this is the first study to assess the relationship between
227 food intake, nutrient adequacy of the diet and nutritional biological parameters systematically
228 measured before, three and twelve months after GBP and SG. In this study where the patients
229 had similar clinical characteristics at baseline (except for T2D prevalence), our main findings
230 are: (i) protein intake significantly decreases after both GBP and SG, inducing mild protein
231 depletion in more than a third of the patients one year after both surgical techniques; (ii) even
232 though patients after GBP experienced greater weight loss than after SG, both types of
233 surgery induced similar food restriction effects on the nutritional adequacy of the diet and,
234 (iii) systematic multivitamin and mineral supplementation after SG seems to prevent these
235 nutritional deficiencies, the same way as in GBP in the first year.

236 After one year, we observed that GBP led to significantly greater weight loss
237 compared to SG, in accordance with previous data from the literature, including a large
238 multicenter study [33,34]. Nevertheless, some controversy remains. Indeed other reports show
239 that changes in body weight were similar one year after both GBP and SG [15,19,35],
240 although these were smaller cohorts. We evaluated the evolution of body composition and
241 observed that, in both surgeries, total FFM decreased until three months and then stabilized,
242 whereas total FM displayed a continuous decrease during the follow-up. Our results are
243 consistent with previous reports showing changes in body composition following GBP [22] or
244 SG [36] as measured by DXA. Our results are also concordant with the only study comparing
245 these outcomes after both sleeve and by-pass [19]. In that study, the continuous weight loss
246 during one year was due to the decrease of total FM, the total FFM being spared after four
247 months [19]. More importantly, we observed that appendicular FFM decreased until three
248 months and then stabilized, whereas appendicular FM continued to decrease throughout the

249 follow-up period in both models. Appendicular FFM represents a better surrogate of muscle
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2 250 mass than total FFM [37], and this is the first time that this outcome and its evolution have
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4 251 been studied after SG. Interestingly, the change in appendicular FFM was similar in the two
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7 252 surgical procedures.
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10 253 After both BS, we observed that 61% of the patients reported daily protein
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12 254 consumption under the recommended value of 60 g/day at T12 (64% for GBP and 58% for
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14 255 SG). Our results are consistent with those of Andreu *et al.* and Moizé *et al.* who found that
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17 256 respectively 37% and 46% of patients had a daily protein intake below 60 g/day one year after
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19 257 BS [19,38]. In accordance with those findings, we did not find any difference between GBP
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22 258 and SG [38]. We report a prevalence of insufficient protein intake that is nearly 2-fold higher
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24 259 than that reported by Moizé *et al.* (61% versus 37%), which is mostly attributable to the
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27 260 systematic protein supplementation prescribed by these authors to all of their patients [38].
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29 261 One objective of recommending a minimal protein intake of 60 g/day after both GBP and SG
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31 262 is to mitigate post-surgical FFM loss in the first months [17]. Indeed, Moizé *et al.*
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34 263 demonstrated that patients with insufficient protein intake during the follow-up lost more
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36 264 FFM in both SG and GBP than patients with sufficient protein intake [19]. Because skeletal
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39 265 muscle is the primary site of insulin-stimulated glucose disposal during euglycemia [39], loss
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41 266 of FFM might contribute to the development of insulin resistance and should be avoided in
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44 267 order to maintain the beneficial metabolic outcomes. An important goal of future long-term
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46 268 follow-up studies will be to determine whether insufficient protein intake following BS might
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49 269 result in loss of muscular strength. Furthermore, longer-term weight stabilization (and regain)
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51 270 should also be assessed in link with the quantity of protein intake.
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53 271 After both BS, we also observed that prealbumin concentration significantly
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56 272 decreased, resulting in more than a third of patients exhibiting mild protein depletion. Our
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58 273 results are in line with the few studies that reported changes in prealbumin concentration after
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274 GBP or SG. All studies found lower values at T12 after GBP compared to baseline
1 [15,40,41]. Results with SG are more heterogeneous, with reports showing both lower [42] or
2 275 [15,40,41]. Results with SG are more heterogeneous, with reports showing both lower [42] or
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4 276 no change in prealbumin concentrations [15,41]. Of note, Moizé *et al.* reported that 14% of
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7 277 GBP and 16% of SG patients experienced abnormalities in prealbumin concentrations at T12
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10 278 after BS [14]. As mentioned above, this difference may be due to the systematic prescription
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12 279 of protein supplement in the Hospital Clinic of Barcelona [19,38]. Adequate protein intake
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14 280 after BS is of utmost importance to prevent the patients from experiencing hair loss, poor
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17 281 wound healing and adverse effects such as infections after skin repair surgery and ultimately –
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19 282 but rarely – protein-calorie malnutrition [43,44].
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22 283 Although SG merely restricts the volume of the stomach without intestinal
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24 284 malabsorption [5], it also leads to an accelerated gastric emptying. Subsequently faster
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26 285 gastrointestinal passage might promote nutrient deficiencies [45], as observed in a recent
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29 286 study with increased faecal excretion of fatty acids [46], resulting in a state of moderate
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32 287 malabsorption. Furthermore, SG decreases gastric intrinsic factor and gastric acid production,
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34 288 two factors involved in vitamin B-12 and iron absorption. Because most of our patients took
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36 289 the prescribed daily multivitamin and mineral supplements one year after both GBP and SG,
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39 290 few patients experienced nutritional abnormalities (except for 25(OH)-vitamin-D3) and there
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41 291 was no difference between the two surgical groups. Our results were consistent with previous
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44 292 data from the literature [14,15]. Conversely, others reported a higher risk of vitamin B-12 and
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46 293 25(OH)-vitamin-D3 deficiencies after GBP compared to SG [12]. It should be noted that in
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49 294 these three studies, patients undergoing GBP or SG were instructed to take multivitamin and
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51 295 mineral supplements on a daily basis after BS. Another point to take into account, is the risk
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54 296 of developing undesirably high levels of micronutrient concentrations due to the systematic
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56 297 supplementation as was previously reported after SG [7,8,11]. Herein, we only identified one
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58 298 patient with serum thiamin and another with serum ferritin above normal range. Nevertheless,
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299 it should be noted that the risk of excessive levels in those studies were mostly observed for
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2 300 vitamin A and B-6, which we did not assess. Altogether, these data highlight the importance
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4 301 to prescribe daily multivitamin and mineral supplements after both GBP and SG at least in the
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7 302 first year, but also to monitor the adherence of the patients to their supplementation.
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9 303 At baseline, the higher prevalence of glucose intolerance in patients undergoing GBP
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11 304 reflects the process of selection for different BS techniques, where GBP is the first choice for
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14 305 patients with T2D or glucose intolerance since it demonstrated its superiority over SG to
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17 306 improve glycemic status post-surgery [35]. We also observed that neither GBP nor SG
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19 307 enabled a significant improvement of HBP in terms of overall prevalence. Nevertheless, both
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22 308 the number of patients treated and the number of treatments per patients tended to decrease
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24 309 after both surgeries, suggesting slight improvement of HBP in this cohort of obese patients
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27 310 with many comorbidities. Nevertheless our data are in accordance with previous studies,
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29 311 which indicated that HBP may not be the best resolved comorbidity after surgery [47,48].
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31 312 One of the main strengths of our study is the use of a validated web-based method of
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34 313 dietary assessment which allowed us to provide detailed quantification of the food and
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36 314 nutrient intake for each patient [24]. This method allows us to assess the use of multivitamin
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39 315 and mineral supplements and measure adherence of the patients to the supplementation.
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41 316 Although the interventions were not randomized in our study, our participants had
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44 317 comparable clinical characteristics at baseline (except for T2D) and were provided the same
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46 318 systematic supplementation regardless of the surgical procedure. The main limitation
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49 319 concerns the relative small number of patients, especially in the group who completed the one
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51 320 year follow-up. This may have prevented us from detecting changes between FFM loss and
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53 321 low protein intake after both procedures. Future studies with longer follow-up periods and
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56 322 larger sample size are needed to determine how poor dietary habits and nutritional
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58 323 deficiencies correlate with weight maintenance at longer term and with the improvement or
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1 324 resolution of obesity related co-morbidities. We intend to follow this cohort in the second
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7 327 In conclusion, we observed similar food restriction effects on the nutritional adequacy
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9 328 of the diet in the first year post GBP and SG surgery. We also observed comparable
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11 329 consequences in terms of biochemical evolution and micronutrient serum concentrations.
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13 330 Altogether, our results advocate for a cautious monitoring of protein intake and a systematic
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15 331 multivitamin and mineral supplementation after both GBP and SG – at least in the first year
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17 332 for SG.

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23 334 **Conflict of interest.** The authors declare that they have no conflict of interest.
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TABLES

TABLE 1. Anthropometric parameters and clinical characteristics according the surgical models at baseline, 3 months, 6 months and 12 months¹.

	GBP				SG			
	Baseline n=22	3 months n=22	6 months n=22	12 months n=14	Baseline n=30	3 months n=30	6 months n=30	12 months n=19
Age, years	43.5 (38.0-51.0)	/	/	/	41.0 (36.0-49.0)	/	/	/
Sex (% female)	68.2	/	/	/	66.7	/	/	/
Anthropometric parameters								
Weight, kg	127 (113-139) ^d	101 (94-115) ^c	89 (83-106) ^b	83 (79-92) ^a	117 (108-137) ^d	98 (90-116) ^c	94 (81-111) ^b	103 (84-109) ^a
BMI, kg/m ²	45.5 (41.6-49.1) ^d	37.0 (33.6-42.0) ^c	33.5 (31.3-37.2) ^b	30.6 (27.8-33.6) ^a	43.2 (39.0-47.7) ^d	35.5 (32.8-41.7) ^c	35.6 (29.9-40.9) ^b	38.5 (29.2-41.1) ^a
Weight loss, kg	0.0 (0.0-0.0) ^a	23.2 (19.8-27.2) ^b	32.4 (28.0-38.4) ^c	38.8 (29.0-48.6) ^d	0.0 (0.0-0.0) ^a	18.3 (15.4-22.9) ^b	23.9 (18.7-29.9) ^{*c}	27.2 (25.6-33.0) ^{*d}
Fat free mass (%)	51.8 ^a	53.9 ^b	57.7 ^c	59.9 ^d	50.9 ^a	53.1 ^b	56.3 ^c	54.9 ^c
Fat mass (%)	45.8 ^d	43.2 ^c	39.4 ^b	36.9 ^a	46.6 ^c	44.0 ^b	40.7 ^a	42.2 ^a
Obesity related-diseases								
Type-2 diabetes, N (%)	12 (54) ^b	4 (18) ^a	4 (18) ^a	3 (21) ^a	10 (33)	7 (23)	7 (23)	3 (16)
Glucose intolerance, N (%)	16 (73) ^b	4 (18) ^a	4 (18) ^a	3 (21) ^a	10 (33) [*]	7 (23)	7 (23)	3 (16)
OSA, N (%)	14 (64) ^b	13 (59) ^b	10 (45) ^b	3 (21) ^a	15 (50)	14 (48)	8 (27)	7 (37)
Dyslipidemia, N (%)	20 (91) ^b	18 (81) ^b	17 (77) ^b	5 (36) ^a	26 (87) ^b	21 (72) ^b	13 (43) ^a	6 (32) ^a
HBP, N (%)	12 (54)	11 (50)	8 (36)	5 (36)	9 (30)	9 (30)	9 (30)	7 (37)
Treatment for HBP, N (mean number of treatment)	12 (2.1)	/	7 (1.6)	5 (1.6)	9 (2.8)	/	9 (1.9)	6 (2.0)

¹Labeled medians or percentages without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction or paired McNemar test. *Represents significant differences between GBP and SG. *Glucose intolerance is defined as either fasting hyperglycemia (1g/l ≤G< 1.26g/l) or 6%≤HBA1c<6.5%); dyslipidemia is defined as a patient with treatment (statin or fibrate) or hypertriglyceridemia ≥1.5g/l or hypoHDL<0.5g/l for women and hypoHDL<0.4g/l for men; High blood pressure (HBP) is defined as a systolic blood pressure >140 mmHg and/or a diastolic blood pressure > 90mmHg or patients with an anti-hypertensive treatment; obstructive sleep apnea (OSA) is defined as an Index Apnea Hypopnea >5/hour with or without treatment.)*

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TABLE 2. Energy, food and macronutrient intakes according to the surgical models at baseline, 3 months and 12 months¹.

	GBP			SG		
	Baseline n=22	3 months n=22	12 months n=14	Baseline n=30	3 months n=30	12 months n=19
Energy and food intakes						
Energy intake, <i>kcal/d</i>	2005 (1539-2266) ^c	711 (615-1006) ^a	1226 (8133-1559) ^b	1658 (1445-2395) ^c	833 (539-1108) ^a	1078 (793-1354) ^b
BMR, <i>kcal/d</i>	2179 (2005-2409) ^c	1770 (1702-2072) ^b	1653 (1480-1791) ^a	1959 (1853-2218) ^c	1742 (1593-1894) ^b	1686 (1565-1963) ^a
Fruit and vegetables, <i>servings/d</i>	4.8 (3.2-7.0) ^b	2.2 (0.8-3.2) ^a	2.1 (1.5-3.9) ^{ab}	3.0 (1.6-4.3) ^b	1.5 (0.8-2.1) ^a	1.4 (1.0-2.6) ^{ab}
Starchy foods, <i>servings/d</i>	2.8 (2.1-3.7) ^b	0.7 (0.3-1.2) ^a	1.1 (0.8-1.6) ^a	2.6 (2.1-3.3) ^c	0.7 (0.3-1.1) ^a	1.2 (0.7-1.7) ^b
Dairy products, <i>servings/d</i>	2.1 (1.3-3.1)	1.7 (0.5-2.6)	2.1 (0.8-2.5)	1.6 (1.0-2.4)	1.4 (0.6-1.9)	1.2 (0.7-1.7)
Meat and fish, <i>servings/d</i>	1.4 (1.0-2.6) ^b	0.8 (0.6-1.1) ^a	0.7 (0.4-1.6) ^{ab}	1.6 (1.1-2.5) ^b	0.9 (0.6-1.4) ^a	1.0 (0.7-1.8) ^{ab}
Macronutrient intakes						
Protein, <i>g/d</i>	83.5 (70.6-105.6) ^c	41.7 (24.0-49.0) ^a	50.4 (36.9-65.2) ^b	78.3 (64.0-107.2) ^c	41.2 (26.8-52.6) ^a	51.8 (36.4-65.3) ^b
N (%) < 60g/d	2 (9) ^a	19 (86) ^b	9 (64) ^b	4 (13) ^a	26 (87) ^b	11 (58) ^b
Protein, <i>g/kg/d</i>	0.66 (0.57-0.73) ^b	0.38 (0.24-0.46) ^a	0.59 (0.48-0.715) ^b	0.65 (0.57-0.80) ^c	0.39 (0.29-0.50) ^a	0.46 (0.39-0.74) ^b
Total Lipid, % <i>EI/d</i>	32.0 (30.0-40.6)	36.8 (32.4-39.3)	38.8 (33.6-45.6)	37.4 (33.2-39.9)	41.6 (35.8-44.7)	39.5 (37.1-44.5)
SFA, % <i>EI/d</i>	14.7 (11.3-16.4)	15.5 (13.1-16.6)	17.4 (13.7-20.9)	15.6 (14.5-18.7)	17.4 (15.3-19.6)	15.8 (13.7-19.4)
PUFA, % <i>EI/d</i>	4.8 (4.2-5.8)	4.3 (3.2-6.4)	3.5 (3.0-5.5)	5.0 (4.0-5.9)	5.0 (3.3-6.4)	5.6 (4.3-8.0)
Total Carbohydrate, % <i>EI/d</i>	47.8 (42.0-49.7)	44.0 (38.9-49.2)	42.2 (35.4-47.1)	44.1 (40.0-46.7)	37.4 (32.3-46.8)	42.4 (33.4-45.1)

¹Labeled medians or percentages without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction or paired McNemar test.

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TABLE 3. Multivitamin and mineral supplementation, PANDiet scores and probabilities of nutrient adequacy according to the surgical models at baseline, 3 months and 12 months¹

	GBP			SG		
	Baseline n=22	3 months n=22	12 months n=14	Baseline n=30	3 months n=30	12 months n=19
Supplementation, N (%)	3 (14) ^a	17 (77) ^b	12 (86) ^b	3 (10) ^a	23 (77) ^b	13 (68) ^b
PANDiet	67.4 (60.7-70.7)	74.7(61.5-76.3)	71.0 (65.3-75.0)	57.7 (54.0-63.1)	65.3 (57.2-71.3)	65.0 (57.4-73.0)
Moderation Sub-score	64.6 (58.6-85.6)	82.1 (75.6-85.3)	74.3 (61.8-81.2)	63.2 (51.3-73.5) ^a	70.9 (63.83-80.0) ^b	73.1 (66.7-78.1) ^b
Protein	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
Total Carbohydrate	1.00 (1.00-1.00)	1.00 (0.97-1.00)	1.00 (0.98-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
Total Fat	0.99 (.035-1.00)	0.81 (0.58-0.93)	0.59 (0.05-0.95)	0.84 (0.52-0.96)	0.42 (0.02-0.84)	0.57 (0.05-0.89)
SFA	0.19 (0.04-0.61)	0.12 (0.02-0.35)	0.02 (0.00-0.29)	0.05 (0.00-0.30)	0.02 (0.00-0.15)	0.10 (0.00-0.28)
Cholesterol	0.66 (0.36-0.99) ^a	0.99 (0.94-1.00) ^b	0.95 (0.51-0.99) ^{ab}	0.41 (0.15-0.79) ^a	0.98 (0.65-1.00) ^b	1.00 (0.65-1.00) ^b
Sodium	0.43 (0.18-0.77) ^a	1.00 (0.96-1.00) ^c	0.97 (0.71-1.00) ^b	0.51 (0.01-0.78) ^a	1.00 (0.97-1.00) ^b	0.99 (0.70-1.00) ^b
Adequacy Sub-score	63.7 (53.3-76.6)	69.4 (62.7-70.7)	73.2 (66.3-75.6)	51.6 (39.3-69.0)	63.1 (42.1-72.1)	63.2 (38.1-74.3)
Protein	0.51 (0.18-0.78) ^b	0.00 (0.00-0.03) ^a	0.30 (0.05-0.71) ^b	0.47 (0.17-0.81) ^c	0.00 (0.00-0.08) ^a	0.05 (0.00-0.68) ^b
Total Carbohydrate	0.86 (0.20-0.98)	0.43 (0.04-0.82)	0.20 (0.01-0.62)	0.44 (0.03-0.68)	0.09 (0.00-0.75)	0.24 (0.00-0.52)
Total Fat	0.69 (0.50-1.00)	0.93 (0.70-0.99)	1.00 (0.85-1.00)	1.00 (0.82-1.00)	0.99 (0.84-1.00)	1.00 (0.93-1.00)
PUFA	0.44 (0.25-0.80)	0.35 (0.07-0.73)	0.14 (0.02-0.60)	0.49 (0.21-0.76)	0.49 (0.07-0.83)	0.66 (0.24-0.91)
Fibre	0.19 (0.02-0.54) ^c	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^b	0.02 (0.00-0.06) ^c	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^b
Vitamin A	0.78 (0.35-0.94)	1.00 (0.74-1.00)	1.00 (1.00-1.00)	0.67 (0.44-0.96)	0.99 (0.53-1.00)	0.67 (0.01-1.00)
Thiamin	0.85 (0.48-0.98)	1.00 (0.90-1.00)	1.00 (1.00-1.00)	0.61 (0.34-0.81)	1.00 (0.40-1.00)	0.97 (0.05-1.00)
Riboflavin	0.96 (0.81-0.98)	1.00 (0.91-1.00)	1.00 (1.00-1.00)	0.83 (0.57-0.93)	1.00 (0.65-1.00)	0.97 (0.41-1.00)
Niacin	0.99 (0.76-1.00)	1.00 (0.99-1.00)	1.00 (1.00-1.00)	0.93 (0.85-0.99)	1.00 (0.89-1.00)	1.00 (0.65-1.00)
Vitamin B-6	0.81 (0.54-0.99)	1.00 (0.77-1.00)	1.00 (1.00-1.00)	0.44 (0.11-0.96)	1.00 (0.17-1.00)	0.98 (0.04-1.00)
Folate	0.85 (0.32-0.97)	0.94 (0.58-1.00)	0.98 (0.94-1.00)	0.56 (0.30-0.81)	0.86 (0.42-0.99)	0.86 (0.02-1.00)
Vitamin B-12	0.88 (0.75-0.98)	0.81 (0.42-0.96)	0.94 (0.84-1.00)	0.87 (0.76-0.97)	0.91 (0.77-0.99)	0.83 (0.66-1.00)

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Vitamin C	0.75 (0.25-0.95)	1.00 (0.64-1.00)	1.00 (1.00-1.00)	0.26 (0.00-0.82) ^a	1.00 (0.56-1.00) ^b	0.94 (0.06-1.00) ^{ab}
Vitamin D	0.01 (0.00-0.20) ^a	0.99 (0.50-1.00) ^b	1.00 (0.97-1.00) ^b	0.02 (0.00-0.58) ^a	0.96 (0.17-1.00) ^b	0.71 (0.31-0.99) ^b
Vitamin E	0.34 (0.11-0.94)	0.97 (0.46-1.00)	1.00 (0.95-1.00)	0.18 (0.02-0.44)	0.95 (0.03-0.99)	0.71 (0.17-1.00)
Calcium	0.87 (0.70-0.97)	1.00 (0.93-1.00)	1.00 (0.98-1.00)	0.82 (0.43-0.97)	0.85 (0.02-1.00)	0.44 (0.04-1.00)
Magnesium	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.00 (0.00-0.00)
Zinc	0.75 (0.37-0.94)	1.00 (0.86-1.00)	1.00 (1.00-1.00)	0.58 (0.27-0.86)	1.00 (0.15-1.00)	0.94 (0.13-1.00)
Phosphorus	1.00 (1.00-1.00) ^c	0.59 (0.03-0.96) ^a	0.90 (0.78-0.99) ^b	0.99 (0.96-1.00) ^c	0.60 (0.04-0.87) ^a	0.86 (0.14-1.00) ^b
Potassium	0.69 (0.45-0.93) ^b	0.01 (0.00-0.29) ^a	0.01 (0.00-0.15) ^a	0.39 (0.14-0.89) ^c	0.00 (0.00-0.02) ^a	0.03 (0.00-0.12) ^b
Iron	0.93 (0.85-1.00)	1.00 (0.85-1.00)	1.00 (0.96-1.00)	0.93 (0.55-1.00)	1.00 (0.45-1.00)	0.85 (0.15-1.00)

¹Labeled medians or percentages without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction or paired McNemar test.

TABLE 4. Metabolic and nutritional parameters according the surgical models at baseline, 3 months, 6 months and 12 months¹

	GBP				SG			
	Baseline n=22	3 months n=22	6 months n=22	12 months n=14	Baseline n=30	3 months n=30	6 months n=30	12 months n=19
Hemoglobin (g/dl)	13.9 (13.0-14.7)	13.9 (13.4-14.7)	13.8 (13.5-14.1)	13.7 (13.3-14.1)	13.7 (13.2-14.5)	13.7 (12.9-14.4)	13.6 (13.1-14.1)	13.4 (13.0-14.1)
<12 g/dl N(%)	2 (9)	0 (0)	1 (5)	1 (7)	0 (0)	1 (3)	0 (0)	1 (5)
Ferritin (µg/l)	115 (62-201)	86 (69-188)	96 (65-199)	100 (58-166)	121 (39-230)	154 (92-266)	144 (92-234)	144 (82-176)
<30 µg/l N(%)	3 (14)	0 (0)	1 (5)	1 (7)	3 (10)	1 (3)	1 (3)	1 (5)
Iron (µmol/l)	14.0 (10.0-16.0)	13.0 (12.0-17.0)	15.0 (13.0-18.0)	15.0 (12.0-18.0)	15.0 (12.0-22.0)	16.0 (14.0-19.0)	17.0 (13.0-19.0)	16.5 (13.0-19.0)
<9 µmol/l N (%)	4 (18)	0 (0)	0 (0)	0 (0)	2 (7)	2 (7)	0 (0)	1 (5)
Transferrin (g/l)	3.1 (2.7-3.1)	2.3 (2.2-2.8)	2.4 (2.1-2.8)	2.5 (2.0-2.8)	2.7 (2.5-2.9)	2.4 (2.2-2.7)	2.5 (2.3-2.7)	2.6 (2.3-2.7)
>3.1 g/l N(%)	3 (14)	2 (9)	2 (9)	1 (7)	3 (10)	0 (0)	1 (3)	0 (0)
Total iron binding capacity (µmol/l)	67.5 (61.0-76.0)	58.0 (55.0-71.0)	59.0 (53.0-69.0)	62.0 (51.0-70.0)	66.5 (61.0-72.0)	61.0 (56.0-67.0)	62.0 (58.0-67.0)	64.0 (57.0-67.0)
>80 µmol/l N(%)	1 (5)	2 (9)	1 (5)	1 (7)	2 (7)	0 (0)	1 (3)	0 (0)
Transferrin saturation coefficient (%)	0.21 (0.16-0.26)	0.22 (0.17-0.24)	0.25 (0.19-0.32)	0.24 (0.19-0.33)	0.25 (0.18-0.33)	0.29 (0.23-0.33)	0.28 (0.20-0.32)	0.25 (0.23-0.29)
<0.15% N(%)	5 (23)	3 (14)	1 (5)	3 (21)	2 (7)	1 (3)	1 (3)	1 (5)
Albumin (g/l)	35.5 (33.0-37.0) ^a	39.0 (36.0-41.0) ^b	38.0 (36.0-41.0) ^b	39.0 (37.0-40.0) ^b	37.0 (35.0-39.0) ^a	40.0 (37.0-42.0) ^b	40.0 (38.0-42.0) ^b	41.0 (38.0-42.0) ^b
<37 g/l N(%)	13 (59)	7 (32)	6 (27)	3 (21)	14 (47)	6 (20)	2 (7)	3 (16)
Prealbumin (g/l)	0.25 (0.19-0.30) ^b	0.20 (0.16-0.21) ^a	0.20 (0.19-0.22) ^a	0.20 (0.18-0.0.25) ^{ab}	0.23 (0.21-0.25) ^b	0.18 (0.17-0.21) ^a	0.19 (0.18-0.21) ^a	0.19 (0.18-0.22) ^a
<0.2 g/L N(%)	6 (27)	8 (37)	10 (45)	5 (38)	5 (17) ^a	17 (57) ^b	15 (50) ^b	10 (52) ^b
Calcium (mmol/l)	2.29 (2.24-2.37)	2.39 (2.33-2.43)	2.37 (2.28-2.39)	2.31 (2.26-2.39)	2.31 (2.24-2.38)	2.37 (2.31-2.44)	2.31 (2.28-2.38)	2.33 (2.31-2.38)
25(OH)-vitamin-D3 (ng/ml)	13.0 (10.0-23.0) ^a	/	29.5 (26.5-32.0) ^b	27.0 (22.0-29.0) ^b	17.0 (11.0-23.0) ^a	/	26.9 (22.5-30.5) ^b	25.0 (20.0-30.0) ^b
<30 ng/ml N(%)	19 (86)	/	10 (45)	10 (71)	25 (83)	/	18 (60)	13 (68)
Parathyroid hormone (pg/ml)	48.3 (41.5-58.9)	/	/	44.1 (35.1-47.1)	46.8 (36.4-54.0)	/	/	39.5 (32.3-43.3)
>45 pg/ml N(%)	13 (59)	/	/	6 (43)	15 (50)	/	/	4 (21)
Thiamin (nmol/l)	157 (150-174)	/	193 (155-193)	197 (174-215)	147 (134-175)	/	177 (158-191)	181 (149-218)
<126 nmol/l N(%)	2 (9)	/	1 (5)	0 (0)	5 (17)	/	1 (3)	0 (0)

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Erythrocyte folate (nmol/l)	1287 (1023-1429) /	1760 (1457-1961)	1940 (1421-2169)	1234 (1036-1377) ^a /	1411 (1246-1806) ^b	1540 (1366-1804) ^b
<945 nmol/l N(%)	4 (18) /	2 (9)	0 (0)	5 (17) /	0 (0)	0 (0)
Serum folate (nmol/l)	16.8 (12.9-24.0) /	26.9 (22.8-33.4)	27.9 (22.8-41.0)	17.7 (14.7-20.5) ^a /	22.8 (18.4-28.4) ^b	20.2 (15.6-26.4) ^b
Vitamin B-12 (pmol/l)	284 (209-334) /	252 (227-345)	221 (195-278)	293 (248-358) /	311 (224-464)	311 (216-432)
<140 pmol/l N(%)	1 (5) /	1 (5)	0 (0)	1 (3) /	0 (0)	0 (0)

¹Labeled medians or percentages without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction or paired McNemar test. *Normal ranges are as follows: hemoglobin [12-17] g/dl; ferritin [30-300] µg/l; iron [9-27] µmol/l; transferrin [1.7-3.1] g/l; total iron binding capacity [40-80] µmol/l; transferrin saturation coefficient [0.15-0.35] %; albumin [37-50] g/l; prealbumin [0.2-0.35] g/l; calcium [2.1-2.65] mmol/l; 25(OH)-vitamin-D3 [30-100] ng/ml; thiamin [126-250] nmol/l; serum folate [7-39.5] nmol/l, vitamin B-12 [140-490] pmol/l.*

FIGURE LEGENDS

FIGURE 1. Changes in body composition in the GBP and SG groups at baseline (T0) and along the follow-up (T3, T6 and T12).

Results are expressed as means \pm SDs. Evolution of body composition during follow-up. Gastric sleeve in grey and GBP in black; top left panel fat free mass; top right panel total fat mass, low left panel appendicular fat free mass (i.e. arms + legs), low right panel appendicular fat mass. Labeled means without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction. No significant difference between GBP and SG was observed.

SUPPLEMENTAL DATA

SUPPLEMENTAL TABLE 1. PANDiet scores and probabilities of nutrient adequacy according to the surgical models at baseline, 3 months and 12 months (calculated from foods only)¹

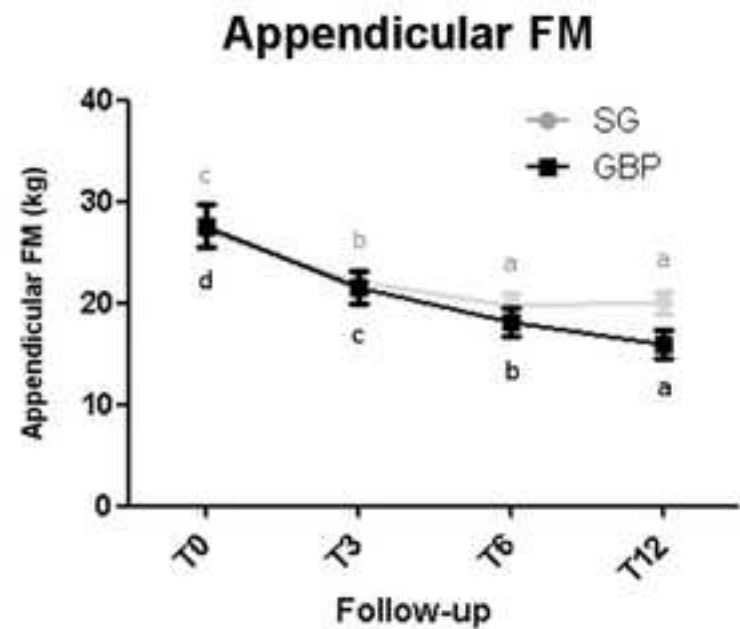
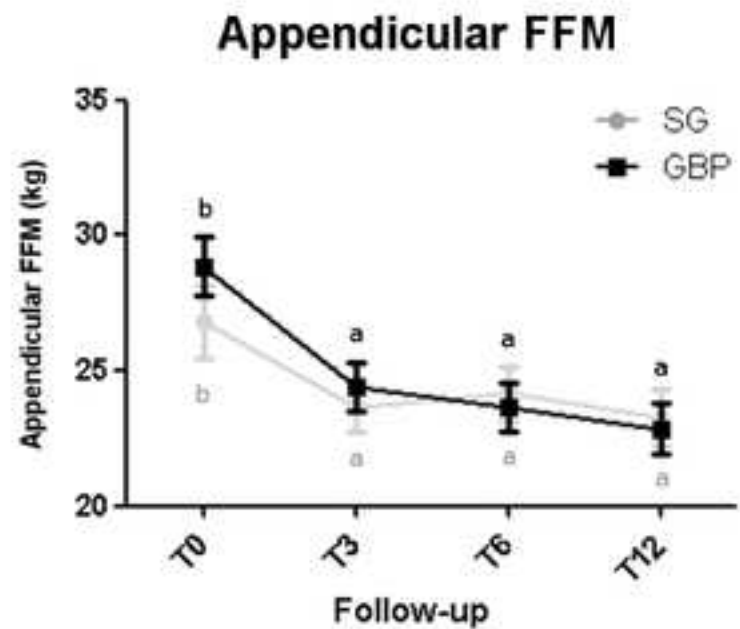
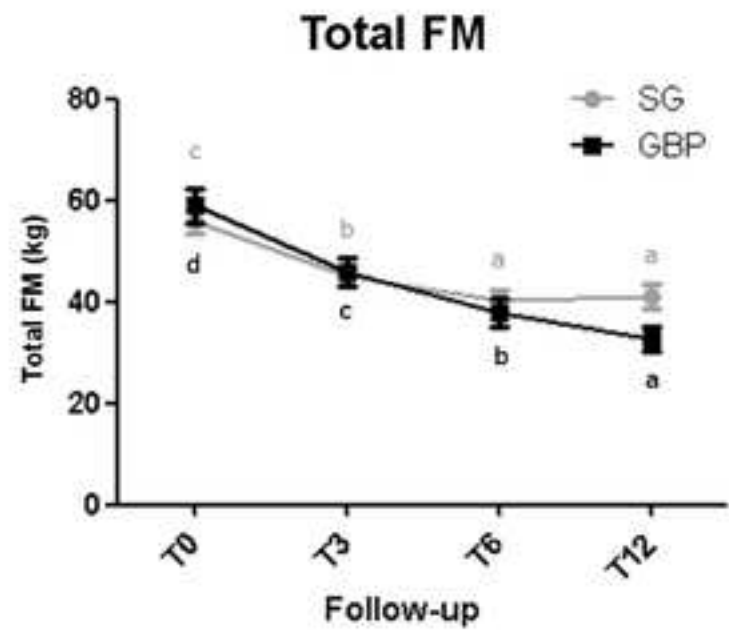
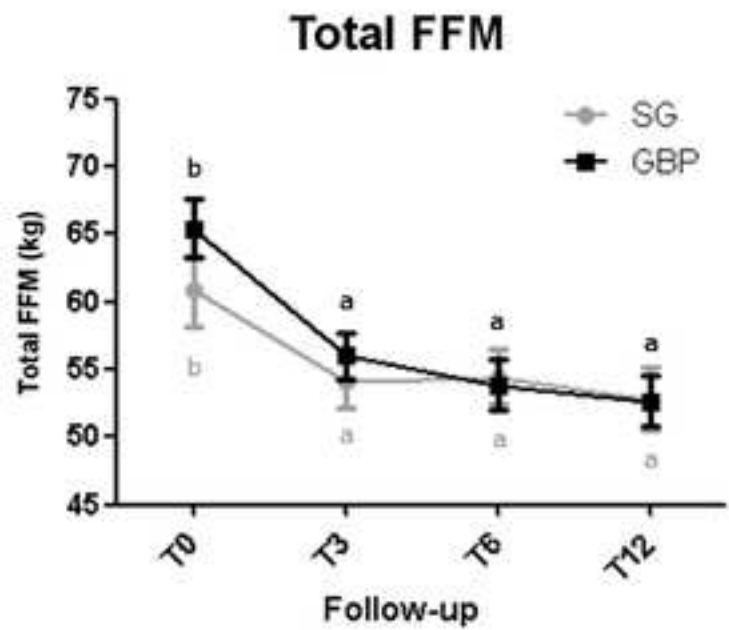
	GBP			SG		
	Baseline n=22	3 months n=22	12 months n=14	Baseline n=30	3 months n=30	12 months n=19
PANDiet	66.0 (60.7-70.5) ^b	51.6 (47.8-53.7) ^a	52.1 (46.1-57.6) ^a	57.7 (54.0-62.1) ^b	47.6 (40.9-53.0) ^a	52.9 (46.7-60.6) ^b
Moderation Sub-score	64.6 (58.6-85.6)	82.1 (75.6-85.3)	74.3 (61.8-81.2)	63.2 (51.3-73.5) ^a	70.9 (63.8-80.0) ^b	73.1 (66.7-78.1) ^b
Protein	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
Total Carbohydrate	1.00 (1.00-1.00)	1.00 (0.97-1.00)	1.00 (0.98-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)	1.00 (1.00-1.00)
Total Fat	0.99 (0.93-1.00)	0.81 (0.58-0.93)	0.59 (0.05-0.95)	0.84 (0.52-0.96)	0.42 (0.02-0.84)	0.57 (0.05-0.89)
SFA	0.19 (0.04-0.61)	0.12 (0.02-0.35)	0.02 (0.00-0.29)	0.05 (0.00-0.30)	0.02 (0.00-0.15)	0.10 (0.00-0.28)
Cholesterol	0.66 (0.36-0.99) ^a	0.99 (0.94-1.00) ^b	0.95 (0.51-0.99) ^{ab}	0.41 (0.15-0.79) ^a	0.98 (0.65-1.00) ^b	1.00 (0.65-1.00) ^b
Sodium	0.43 (0.18-0.77) ^a	1.00 (0.96-1.00) ^c	0.97 (0.71-1.00) ^b	0.51 (0.01-0.78) ^a	1.00 (0.97-1.00) ^b	0.99 (0.70-1.00) ^b
Adequacy Sub-score	60.8 (53.0-72.0) ^b	22.1 (14.9-34.5) ^a	30.3 (22.8-42.8) ^a	51.6 (38.4-69.0) ^c	20.6 (11.9-35.2) ^a	27.0 (16.8-44.4) ^b
Protein	0.51 (0.18-0.78) ^b	0.00 (0.00-0.03) ^a	0.30 (0.05-0.71) ^b	0.47 (0.17-0.81) ^c	0.00 (0.00-0.08) ^a	0.05 (0.00-0.68) ^b
Total Carbohydrate	0.86 (0.20-0.98)	0.43 (0.04-0.82)	0.20 (0.01-0.62)	0.44 (0.03-0.68)	0.09 (0.00-0.75)	0.24 (0.00-0.52)
Total Fat	0.69 (0.50-1.00)	0.93 (0.70-0.99)	1.00 (0.85-1.00)	1.00 (0.82-1.00)	0.99 (0.84-1.00)	1.00 (0.93-1.00)
PUFA	0.44 (0.25-0.80)	0.35 (0.07-0.73)	0.14 (0.02-0.60)	0.49 (0.21-0.76)	0.49 (0.07-0.83)	0.66 (0.24-0.91)
Fibre	0.19 (0.02-0.54) ^c	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^b	0.02 (0.00-0.06) ^c	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^b
Vitamin A	0.71 (0.30-0.91) ^b	0.12 (0.00-0.51) ^a	0.43 (0.05-0.70) ^{ab}	0.67 (0.44-0.96) ^b	0.07 (0.00-0.61) ^a	0.16 (0.00-0.59) ^a
Thiamin	0.84 (0.48-0.97) ^b	0.01 (0.00-0.19) ^a	0.16 (0.01-0.42) ^a	0.56 (0.31-0.77) ^b	0.02 (0.00-0.32) ^a	0.01 (0.00-0.35) ^a
Riboflavin	0.89 (0.79-0.98) ^b	0.06 (0.01-0.67) ^a	0.12 (0.03-0.75) ^a	0.83 (0.57-0.93) ^b	0.21 (0.00-0.46) ^a	0.08 (0.00-0.70) ^a
Niacin	0.99 (0.76-1.00) ^b	0.09 (0.00-0.60) ^a	0.54 (0.10-0.82) ^a	0.93 (0.85-0.99) ^b	0.34 (0.00-0.84) ^a	0.68 (0.41-0.98) ^a
Vitamin B-6	0.81 (0.54-0.98) ^b	0.00 (0.00-0.04) ^a	0.00 (0.00-0.28) ^a	0.44 (0.11-0.96) ^b	0.00 (0.00-0.10) ^a	0.01 (0.00-0.08) ^a
Folate	0.83 (0.32-0.97) ^b	0.04 (0.01-0.17) ^a	0.08 (0.01-0.48) ^a	0.56 (0.30-0.81) ^b	0.03 (0.00-0.18) ^a	0.04 (0.01-0.16) ^a
Vitamin B-12	0.88 (0.75-0.98) ^b	0.31 (0.02-0.80) ^a	0.72 (0.38-0.90) ^b	0.87 (0.76-0.97) ^b	0.63 (0.12-0.83) ^a	0.73 (0.25-0.86) ^a

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Vitamin C	0.63 (0.20-0.95) ^b	0.05 (0.00-0.57) ^{ab}	0.09 (0.00-0.47) ^a	0.26 (0.00-0.82) ^b	0.00 (0.00-0.16) ^a	0.04 (0.00-0.21) ^{ab}
Vitamin D	0.00 (0.00-0.10) ^b	0.00 (0.00-0.00) ^a	0.00 (0.00-0.02) ^{ab}	0.02 (0.00-0.30)	0.00 (0.00-0.08)	0.15 (0.00-0.44)
Vitamin E	0.29 (0.08-0.89) ^c	0.00 (0.00-0.00) ^a	0.00 (0.00-0.03) ^b	0.18 (0.02-0.44) ^b	0.00 (0.00-0.01) ^a	0.13 (0.00-0.39) ^b
Calcium	0.87 (0.07-0.97) ^b	0.28 (0.00-0.77) ^a	0.49 (0.07-0.86) ^a	0.82 (0.43-0.97) ^b	0.06 (0.00-0.35) ^a	0.08 (0.00-0.56) ^a
Magnesium	0.00 (0.00-0.00) ^b	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^b	0.00 (0.00-0.00) ^a	0.00 (0.00-0.00) ^a
Zinc	0.72 (0.35-0.90) ^b	0.01 (0.00-0.14) ^a	0.03 (0.01-0.21) ^a	0.58 (0.27-0.86) ^c	0.01 (0.00-0.06) ^a	0.11 (0.00-0.51) ^b
Phosphorus	1.00 (1.00-1.00) ^c	0.59 (0.03-0.96) ^a	0.90 (0.78-0.99) ^b	0.99 (0.96-1.00) ^c	0.60 (0.04-0.87) ^a	0.86 (0.14-1.00) ^b
Potassium	0.69 (0.45-0.93) ^b	0.01 (0.00-0.29) ^a	0.01 (0.00-0.15) ^a	0.39 (0.14-0.89) ^c	0.00 (0.00-0.02) ^a	0.03 (0.00-0.12) ^b
Iron	0.85 (0.65-1.00) ^b	0.04 (0.00-0.55) ^a	0.25 (0.00-0.55) ^a	0.93 (0.55-1.00) ^b	0.10 (0.00-0.45) ^a	0.15 (0.00-0.85) ^a

¹Labeled medians without a common letter differ between time-points for each surgical model, as tested by paired pairwise post hoc comparisons with Holm-Bonferroni correction.

Figure 1
[Click here to download Figure: Figure1.tif](#)



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