Micronutrient and Protein Deficiencies After Gastric Bypass and Sleeve Gastrectomy: a one-year Follow-up

Eric O. Verger, Judith Aron-Wisnewsky, Maria Carlota Dao, Brandon D. Kayser, Jean-Michel Oppert, Jean-Luc Bouillot, Adriana Torcivia, Karine Clément

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

Original Contribution

Eric O. Verger PhD[1,2]*, Judith Aron-Wisnewsky MD, PhD[1,2,3]*, Maria Carlota Dao PhD[1,2], Brandon D. Kayser PhD[1,2], Jean-Michel Oppert MD, PhD[1], Jean-Luc Bouillot MD, PhD[4], Adriana Torcivia MD[5], Karine Clément MD, PhD.[1,2,3]

*These authors contributed equally to this work.

[1]Institute of Cardiometabolism and Nutrition, ICAN, Assistance Publique-Hôpitaux de Paris, Pitié-Salpêtrière hospital, Nutrition department, F-75013, Paris, France. [2]INSERM, UMR_S U1166, NutriOmics team, F-75013, Paris, France. [3]Sorbonne Universités, UPMC University Paris 06, UMR_S 1166 I, ICAN, Nutriomics team, F-75005, Paris, France. [4]Assistance Publique-Hôpitaux de Paris, Visceral surgery Department, Ambroise Paré Hospital, 92100 Boulogne-Billancourt, France. [5]Assistance Publique-Hôpitaux de Paris, Visceral surgery Department, Pitié-Salpêtrière hospital, F-75013, Paris, France

Email addresses: e.verger@ican-institute.org; judith.aron-wisnewsky@psl.aphp.fr; mc.dao@ican-institute.org; b.kayser@ican-institute.org; jean-michel.oppert@psl.aphp.fr; jl.bouillot@apr.aphp.fr; adriana.torcivia@psl.aphp.fr; karine.clement@psl.aphp.fr

Correspondence to:
Dr. Judith Aron-Wisnewsky and Prof. Karine Clément
Institute of Cardiometabolism and Nutrition
Institut E3M, 83 boulevard de l´Hôpital,
75013 Paris, France
Email: judith.aron-wisnewsky@psl.aphp.fr
Tel: 33 (0) 1 42 17 75 41

Running title: Malnutrition after surgery

1

ABSTRACT

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

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

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

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

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

INTRODUCTION

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

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

50 intake [15,19], and Moizé *et al.* evaluated macronutrient and some selected mineral intake

51 during five years after BS [14].

52 Therefore, we aimed to analyze food restriction effects on the nutritional adequacy of

53 the diet, on macro and micronutrient intake evolution as well as their consequences in terms

54 of bioclinical evolution and micronutrient serum level during one year after both GBP and

55 SG.

56

MATERIAL AND METHODS

Patients

59 Obese candidates for either GBP or SG according to the international bariatric surgery

60 guidelines [20] (i.e. body mass index (BMI) $\geq$40kg/m², or $\geq$35kg/m² with at least one severe

61 obesity-related comorbidity) were treated in the Obesity Unit of Pitié-Salpetrière Hospital,

62 Institute of Cardio-metabolism and Nutrition, ICAN, Paris, France. Patients determined the

63 choice of technique, and advised by a multidisciplinary panel, from the hospital based on

64 medical history, level of corpulence and obesity-related comorbidity. Weight stable patients

65 were enrolled consecutively in this prospective non-randomized study from January 2012.

66 Hotel-Dieu hospital ethics committee approved the clinical protocol (number P100503 –

67 IDRCB 2011-A00759-32) which was recorded on clinical trial website (NCT:

68 NCT01655017). Subjects gave their written informed consent prior to the study inclusion.

69 Medical history and clinical evaluation were obtained at baseline and during the

70 follow-up at three (T3), six (T6) and twelve months (T12) as described elsewhere [21]

71 (reviewer #1, comment #1). Anthropometric parameters were estimated by whole-body fan-

72 beam DXA scanning (Hologic Discovery W, software v12.6, 2; Hologic, Bedford, MA), as

73 previously described [22]. Variables from DXA used in the analyses were total and

74 appendicular fat free mass (FFM, in kg), and total and appendicular fat mass (FM, in kg),

4

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].

79

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 $4 \times 100,000$ 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

5

100 National Nutrition and Health Program [28] and expressed in servings per day based on

101 standard serving sizes [29].

102

Nutrient adequacy of the diet

104 Nutrient intake adequacy for each patient was calculated using the PANDiet index

105 [30]. Briefly, probability of adequacy for each nutrient was calculated, ranging from 0 to 1,

106 where 1 represents a 100% probability that the usual intake is adequate (i.e. it satisfies the

107 requirement or is not excessive compared to a reference value). According to this definition,

108 the probabilities of adequacy were computed to obtain the Adequacy sub-score (the higher,

109 the better the intake satisfies the nutrient requirements) and the Moderation sub-score (the

110 higher, the less likely the intake is excessive). The PANDiet score is taken as the mean of the

111 Adequacy and Moderation sub-scores, and ranges from 0 to 100; the higher the score, the

112 better the nutrient adequacy of the diet. As reference values, we used French nutritional

113 recommendations for healthy adults or European Union values when specific

114 recommendations were lacking.

115

Biochemical analyses

117 Blood samples were collected after an overnight fast to measure biochemical

118 parameters using routine techniques as described [31]. Blood count and iron metabolism

119 markers (i.e. ferritin, iron, transferrin, and saturation coefficient) were assessed using routine

120 care method (nephelemetry (reviewer #1, comment #9), ferrozine colorimetry and

121 immunoturbidimetry respectively). Prealbumin was assessed by immunoturbidimetry. Serum

122 concentrations of 25(OH)-vitamin-D3 and parathyroid hormone (PTH) were measured by

123 chemiluminescent assay (310600 Liaison XL Diasorin and 11972103 Modular E 170 Roche,

124 respectively), vitamin B-12 and folate were assessed using immunoanalysis ECL sandwich,

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).

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).

RESULTS

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).

164

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

majority of patients reported protein intake below the recommended value of 60 g/day (85.7%

after GBP and 79% after SG, Table 2). Afterwards, total protein intake slightly but

significantly increased at T12, although it remained below the baseline levels (Table 2).

Furthermore, 61% of the patients reported low dietary protein intake (64% and 58%

respectively for GBP and SG groups, Table 2) at T12. No significant changes in

macronutrient distribution (total fat, SFA, PUFA and total carbohydrates) were observed

during the follow-up in the two groups (T3 and T12, Table 2). Energy, food and

macronutrient intakes were not different between the two groups during the follow-up (T3

and T12, Table 2).

Nutrient adequacy of the diet

At baseline, neither the PANDiet scores nor the probabilities of nutrient adequacy

differed between the two groups (Table 3). Low probabilities of adequacy for protein were

observed in both groups compared to the French adult population [30].

After both BS, the percentage of patients taking the prescribed systematic

multivitamin and mineral supplements significantly increased, from baseline to T3: 14%

versus 77% for GBP and 10% vs. 76.7% for SG, as expected from the recommendations

(Table 3). This high adherence was maintained at T12 with 86% and 68% respectively for

GBP and SG (Table 3). Due to the supplementation, the global nutrient adequacy of the diet

did not drop and rather stabilized along the follow-up (PANDiet score and Adequacy sub-

score were not significantly different at all time points) and the probability of adequacy for

vitamin D was improved (Table 3). Of note, when the global nutrient adequacy of the diet was

calculated without taking into account the prescribed supplementation, we found that it

drastically decreased at T3 and barely increased at T12 (Supplemental Table 1). However,

since the prescribed supplementation neither contains protein, fiber nor phosphorus, lower

9

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).

205

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.

229

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

11

250 these outcomes after both sleeve and by-pass [19]. In that study, the continuous weight loss

251 during one year was due to the decrease of total FM, the total FFM being spared after four

252 months [19]. More importantly, we observed that appendicular FFM decreased until three

253 months and then stabilized, whereas appendicular FM continued to decrease throughout the

254 follow-up period in both models. Appendicular FFM represents a better surrogate of muscle

255 mass than total FFM [37], and this is the first time that this outcome and its evolution have

256 been studied after SG. Interestingly, the change in appendicular FFM was similar in the two

257 surgical procedures.

258   After both BS, we observed that 61% of the patients reported daily protein

259 consumption under the recommended value of 60 g/day at T12 (64% for GBP and 58% for

260 SG). Our results are consistent with those of Andreu *et al.* and Moizé *et al.* who found that

261 respectively 37% and 46% of patients had a daily protein intake below 60 g/day one year after

262 BS [19,38]. In accordance with those findings, we did not find any difference between GBP

263 and SG [38]. We report a prevalence of insufficient protein intake that is nearly 2-fold higher

264 than that reported by Moizé *et al.* (61% versus 37%), which is mostly attributable to the

265 systematic protein supplementation prescribed by these authors to all of their patients [38].

266 One objective of recommending a minimal protein intake of 60 g/day after both GBP and SG

267 is to mitigate post-surgical FFM loss in the first months [17]. Indeed, Moizé *et al.*

268 demonstrated that patients with insufficient protein intake during the follow-up lost more

269 FFM in both SG and GBP than patients with sufficient protein intake [19]. Because skeletal

270 muscle is the primary site of insulin-stimulated glucose disposal during euglycemia [39], loss

271 of FFM might contribute to the development of insulin resistance and should be avoided in

272 order to maintain the beneficial metabolic outcomes. An important goal of future long-term

273 follow-up studies will be to determine whether insufficient protein intake following BS might

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

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

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

300 compared to SG [12]. It should be noted that in these three studies, patients undergoing GBP

301 or SG were instructed to take multivitamin and mineral supplements on a daily basis after BS.

302 Another point to take into account, is the risk of developing undesirably high levels of

303 micronutrient concentrations due to the systematic supplementation as was previously

304 reported after SG [7,8,11]. Herein, we only identified one patient with serum thiamin and

305 another with serum ferritin above normal range. Nevertheless, it should be noted that the risk

306 of excessive levels in those studies were mostly observed for vitamin A and B-6, which we

307 did not assess. Altogether, these data highlight the importance to prescribe daily multivitamin

308 and mineral supplements after both GBP and SG at least in the first year, but also to monitor

309 the adherence of the patients to their supplementation.

310 At baseline, the higher prevalence of glucose intolerance in patients undergoing GBP

311 reflects the process of selection for different BS techniques, where GBP is the first choice for

312 patients with T2D or glucose intolerance since it demonstrated its superiority over SG to

313 improve glycemic status post-surgery [35]. We also observed that neither GBP nor SG

314 enabled a significant improvement of HBP in terms of overall prevalence. Nevertheless, both

315 the number of patients treated and the number of treatments per patients tended to decrease

316 after both surgeries, suggesting slight improvement of HBP in this cohort of obese patients

317 with many comorbidities. Nevertheless our data are in accordance with previous studies,

318 which indicated that HBP may not be the best resolved comorbidity after surgery [47,48]

319 (reviewer #1, comment #4).

320 One of the main strengths of our study is the use of a validated web-based method of

321 dietary assessment which allowed us to provide detailed quantification of the food and

322 nutrient intake for each patient [24]. This method allows us to assess the use of multivitamin

323 and mineral supplements and measure adherence of the patients to the supplementation.

14

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.

341

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

REFERENCES

1. Buchwald H, Avidor Y, Braunwald E, et al. Bariatric surgery: a systematic review and meta-analysis. JAMA. 2004 Oct 13;292(14):1724–37.

2. Mingrone G, Panunzi S, De Gaetano A, et al. Bariatric surgery versus conventional medical therapy for type 2 diabetes. N Engl J Med. 2012 Apr 26;366(17):1577–85.

3. Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2011. Obes Surg. 2013 Apr;23(4):427–36.

4. Chang S-H, Stoll CRT, Song J, et al. The effectiveness and risks of bariatric surgery: an updated systematic review and meta-analysis, 2003-2012. JAMA Surg. 2014 Mar;149(3):275–87.

5. Jacobs M, Bisland W, Gomez E, et al. Laparoscopic sleeve gastrectomy: a retrospective review of 1- and 2-year results. Surg Endosc. 2009 Aug 19;24(4):781–5.

6. Aasheim ET, Hofsø D, Hjelmesaeth J, et al. Vitamin status in morbidly obese patients: a cross-sectional study. Am J Clin Nutr. 2008 Feb;87(2):362–9.

7. Aarts EO, Janssen IMC, Berends FJ. The gastric sleeve: losing weight as fast as micronutrients? Obes Surg. 2011 Feb;21(2):207–11.

8. Damms-Machado A, Friedrich A, Kramer KM, et al. Pre- and postoperative nutritional deficiencies in obese patients undergoing laparoscopic sleeve gastrectomy. Obes Surg. 2012 Jun;22(6):881–9.

9. Pech N, Meyer F, Lippert H, et al. Complications and nutrient deficiencies two years after sleeve gastrectomy. BMC Surg. 2012;12:13.

10. Saif T, Strain GW, Dakin G, et al. Evaluation of nutrient status after laparoscopic sleeve gastrectomy 1, 3, and 5 years after surgery. Surg Obes Relat Dis Off J Am Soc Bariatr Surg. 2012 Oct;8(5):542–7.

11. Van Rutte PWJ, Aarts EO, Smulders JF, et al. Nutrient deficiencies before and after sleeve gastrectomy. Obes Surg. 2014 Oct;24(10):1639–46.

12. Gehrer S, Kern B, Peters T, et al. Fewer nutrient deficiencies after laparoscopic sleeve gastrectomy (LSG) than after laparoscopic Roux-Y-gastric bypass (LRYGB)-a prospective study. Obes Surg. 2010 Apr;20(4):447–53.

13. Kehagias I, Karamanakos SN, Argentou M, et al. Randomized clinical trial of laparoscopic Roux-en-Y gastric bypass versus laparoscopic sleeve gastrectomy for the management of patients with BMI < 50 kg/m2. Obes Surg. 2011 Nov;21(11):1650–6.

14. Moizé V, Andreu A, Flores L, et al. Long-term dietary intake and nutritional deficiencies following sleeve gastrectomy or Roux-En-Y gastric bypass in a mediterranean population. J Acad Nutr Diet. 2013 Mar;113(3):400–10.

15. Coupaye M, Rivière P, Breuil MC, et al. Comparison of nutritional status during the first year after sleeve gastrectomy and Roux-en-Y gastric bypass. Obes Surg. 2014 Feb;24(2):276–83.

16. Kwon Y, Kim HJ, Lo Menzo E, et al. Anemia, iron and vitamin B12 deficiencies after sleeve gastrectomy compared to Roux-en-Y gastric bypass: a meta-analysis. Surg Obes Relat Dis Off J Am Soc Bariatr Surg. 2014 Aug;10(4):589–97.

17. Mechanick JI, Youdim A, Jones DB, et al. Clinical Practice Guidelines for the Perioperative Nutritional, Metabolic, and Nonsurgical Support of the Bariatric Surgery Patient - 2013 Update: Cosponsored by American Association of Clinical Endocrinologists, The Obesity Society, and American Society for Metabolic & Bariatric Surgery. Obes Silver Spring Md. 2013 Mar;21(0 1):S1–27.

18. Freeman RA, Overs SE, Zarshenas N, et al. Food tolerance and diet quality following adjustable gastric banding, sleeve gastrectomy and Roux-en-Y gastric bypass. Obes Res Clin Pract. 2014 Apr;8(2):e115–200.

17

19. Moizé V, Andreu A, Rodríguez L, et al. Protein intake and lean tissue mass retention following bariatric surgery. Clin Nutr Edinb Scotl. 2013 Aug;32(4):550–5.

20. Fried M, Yumuk V, Oppert J-M, et al. Interdisciplinary European Guidelines on metabolic and bariatric surgery. Obes Facts. 2013;6(5):449–68.

21. Abdennour M, Reggio S, Le Naour G, et al. Association of adipose tissue and liver fibrosis with tissue stiffness in morbid obesity: links with diabetes and BMI loss after gastric bypass. J Clin Endocrinol Metab. 2014 Mar;99(3):898–907.

22. Ciangura C, Bouillot J-L, Lloret-Linares C, et al. Dynamics of change in total and regional body composition after gastric bypass in obese patients. Obes Silver Spring Md. 2010 Apr;18(4):760–5.

23. Nielsen BM, Nielsen MM, Toubro S, et al. Past and current body size affect validity of reported energy intake among middle-aged Danish men. J Nutr. 2009 Dec;139(12):2337–43.

24. Touvier M, Kesse-Guyot E, Méjean C, et al. Comparison between an interactive web-based self-administered 24 h dietary record and an interview by a dietitian for large-scale epidemiological studies. Br J Nutr. 2011 Apr;105(7):1055–64.

25. Le Moullec N, Deheeger M, Preziosi P, et al. Validation du manuel-photos utilisé pour l'enquête alimentaire de l'étude SU.VI.MAX. Cah Nutr Diététique. 31(3):158–64.

26. Gesquiere I, Aron-Wisnewsky J, Foulon V, et al. Medication cost is significantly reduced after Roux-en-Y gastric bypass in obese patients. Obes Surg. 2014 Nov;24(11):1896–903.

27. Afssa - Table de composition nutritionnelle des aliments CIQUAL 2008 (French Food Composition Table – CIQUAL 2008). Available from: https://pro.anses.fr/tableciqual/index.htm.

28. Hercberg S, Chat-Yung S, Chaulia M. The French National Nutrition and Health Program: 2001-2006-2010. Int J Public Health. 2008;53(2):68–77.

29. Estaquio C, Kesse-Guyot E, Deschamps V, et al. Adherence to the French Programme National Nutrition Santé Guideline Score is associated with better nutrient intake and nutritional status. J Am Diet Assoc. 2009 Jun;109(6):1031–41.

30. Verger EO, Mariotti F, Holmes BA, et al. Evaluation of a diet quality index based on the probability of adequate nutrient intake (PANDiet) using national French and US dietary surveys. PloS One. 2012;7(8):e42155.

31. Aron-Wisnewsky J, Minville C, Tordjman J, et al. Chronic intermittent hypoxia is a major trigger for non-alcoholic fatty liver disease in morbid obese. J Hepatol. 2012 Jan;56(1):225–33.

32. Ledoux S, Msika S, Moussa F, et al. Comparison of nutritional consequences of conventional therapy of obesity, adjustable gastric banding, and gastric bypass. Obes Surg. 2006 Aug;16(8):1041–9.

33. Hutter MM, Schirmer BD, Jones DB, et al. First report from the American College of Surgeons Bariatric Surgery Center Network: laparoscopic sleeve gastrectomy has morbidity and effectiveness positioned between the band and the bypass. Ann Surg. 2011 Sep;254(3):410–420; discussion 420–422.

34. Lim DM, Taller J, Bertucci W, et al. Comparison of laparoscopic sleeve gastrectomy to laparoscopic Roux-en-Y gastric bypass for morbid obesity in a military institution. Surg Obes Relat Dis Off J Am Soc Bariatr Surg. 2014 Apr;10(2):269–76.

35. Kashyap SR, Bhatt DL, Wolski K, et al. Metabolic effects of bariatric surgery in patients with moderate obesity and type 2 diabetes: analysis of a randomized control trial comparing surgery with intensive medical treatment. Diabetes Care. 2013 Aug;36(8):2175–82.

36. Bužga M, Zavadilová V, Holéczy P, et al. Dietary intake and ghrelin and leptin changes after sleeve gastrectomy. Videosurgery Miniinvasive Tech. 2014 Dec;9(4):554–61.

37. Kim J, Wang Z, Heymsfield SB, et al. Total-body skeletal muscle mass: estimation by a new dual-energy X-ray absorptiometry method. Am J Clin Nutr. 2002 Aug 1;76(2):378–83.

38. Andreu A, Moizé V, Rodríguez L, et al. Protein intake, body composition, and protein status following bariatric surgery. Obes Surg. 2010 Nov;20(11):1509–15.

39. DeFronzo RA, Jacot E, Jequier E, et al. The effect of insulin on the disposal of intravenous glucose. Results from indirect calorimetry and hepatic and femoral venous catheterization. Diabetes. 1981 Dec;30(12):1000–7.

40. Coupaye M, Puchaux K, Bogard C, et al. Nutritional consequences of adjustable gastric banding and gastric bypass: a 1-year prospective study. Obes Surg. 2009 Jan;19(1):56–65.

41. Sallé A, Demarsy D, Poirier AL, et al. Zinc deficiency: a frequent and underestimated complication after bariatric surgery. Obes Surg. 2010 Dec;20(12):1660–70.

42. Friedrich AE, Damms-Machado A, Meile T, et al. Laparoscopic sleeve gastrectomy compared to a multidisciplinary weight loss program for obesity--effects on body composition and protein status. Obes Surg. 2013 Dec;23(12):1957–65.

43. Agha-Mohammadi S, Hurwitz DJ. Nutritional deficiency of post-bariatric surgery body contouring patients: what every plastic surgeon should know. Plast Reconstr Surg. 2008 Aug;122(2):604-13.

44. Faria SL, Faria OP, Buffington C, de Almeida Cardeal M, Ito MK. Dietary protein intake and bariatric surgery patients: a review. Obes Surg. 2011 Nov;21(11):1798–805.

45. Melissas J, Daskalakis M, Koukouraki S, et al. Sleeve Gastrectomy - A "Food Limiting" Operation. Obes Surg. 2008 Jul 29;18(10):1251–6.

46. Damms-Machado A, Mitra S, Schollenberger AE, et al. Effects of Surgical and Dietary Weight Loss Therapy for Obesity on Gut Microbiota Composition and Nutrient Absorption. BioMed Res Int. 2015 Feb 1;2015:e806248.

47. Sjöström L, Narbro K, Sjöström CD, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. Engl J Med. 2007 Aug 23;357(8):741-52.

48. Gesquiere I, Aron-Wisnewsky J, Foulon V, et al. Medication cost is significantly reduced after Roux-en-Y gastric bypass in obese patients. Obes Surg. 2014 Nov;24(11):1896-903.

TABLES

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

	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/m²*	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	59.9d	50.9^a	53.1^b	56.3^c	54.9^c
Fat mass (%)	45.8^d	43.2^c	39.4^b	36.9a	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)
<mark>Treatment for HBP, N (mean number of treatment) (reviewer #1, comment #4)</mark>	<mark>12 (2.1)</mark>	<mark>/</mark>	<mark>7 (1.6)</mark>	<mark>5 (1.6)</mark>	<mark>9 (2.8)</mark>	<mark>/</mark>	<mark>9 (1.9)</mark>	<mark>6 (2.0)</mark>

[1]Labeled 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.)

23

TABLE 2. Energy, food and macronutrient intakes according to the surgical models at baseline, 3 months and 12 months[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
Energy and food intakes						
Energy intake, *kcal/d*	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, *kcal/d*	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, *serving/d*	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, *serving/d*	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, *serving/d*	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, *serving/d*	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, *g/d*	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, *g/kg/d*	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, *%EI/d*	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, *%EI/d*	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, *%EI/d*	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, *%EI/d*	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)

[1]Labeled 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 3. Multivitamin and mineral supplementation, PANDiet scores and probabilities of nutrient adequacy according to the surgical models at baseline, 3 months and 12 months[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
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)

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)

[1]Labeled 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 months[1]

	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 (130-19.0)
<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)

27

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)

[1]Labeled 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.*

28

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 ± 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	3 months	12 months	Baseline	3 months	12 months
	n=22	n=22	n=14	n=30	n=30	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 (.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	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]

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]

[1]Labeled 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.

31

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

Original Contribution

Eric O. Verger PhD[1,2]*, **Judith Aron-Wisnewsky MD, PhD[1,2,3]***, **Maria Carlota Dao PhD[1,2]**, **Brandon D. Kayser PhD[1,2]**, **Jean-Michel Oppert MD, PhD[1]**, **Jean-Luc Bouillot MD, PhD[4]**, **Adriana Torcivia MD[5]**, **Karine Clément MD, PhD.[1,2,3]**

*These authors contributed equally to this work.

[1]Institute of Cardiometabolism and Nutrition, ICAN, Assistance Publique-Hôpitaux de Paris, Pitié-Salpêtrière hospital, Nutrition department, F-75013, Paris, France. [2]INSERM, UMR_S U1166, NutriOmics team, F-75013, Paris, France. [3]Sorbonne Universités, UPMC University Paris 06, UMR_S 1166 I, ICAN, Nutriomics team, F-75005, Paris, France. [4]Assistance Publique-Hôpitaux de Paris, Visceral surgery Department, Ambroise Paré Hospital, 92100 Boulogne-Billancourt, France. [5]Assistance Publique-Hôpitaux de Paris, Visceral surgery Department, Pitié-Salpêtrière hospital, F-75013, Paris, France

Email addresses: e.verger@ican-institute.org; judith.aron-wisnewsky@psl.aphp.fr; mc.dao@ican-institute.org; b.kayser@ican-institute.org; jean-michel.oppert@psl.aphp.fr; jl.bouillot@apr.aphp.fr; adriana.torcivia@psl.aphp.fr; karine.clement@psl.aphp.fr

Correspondence to:
Dr. Judith Aron-Wisnewsky and Prof. Karine Clément
Institute of Cardiometabolism and Nutrition
Institut E3M, 83 boulevard de l´Hôpital,
75013 Paris, France
Email: judith.aron-wisnewsky@psl.aphp.fr
Tel: 33 (0) 1 42 17 75 41

Running title: Malnutrition after surgery

1

ABSTRACT

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

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

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

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

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

INTRODUCTION

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

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

3

51   Therefore, we aimed to analyze food restriction effects on the nutritional adequacy of

52 the diet, on macro and micronutrient intake evolution as well as their consequences in terms

53 of bioclinical evolution and micronutrient serum level during one year after both GBP and

54 SG.

55

MATERIAL AND METHODS

Patients

58   Obese candidates for either GBP or SG according to the international bariatric surgery

59 guidelines [20] (i.e. body mass index (BMI) $\geq$40kg/m², or $\geq$35kg/m² with at least one severe

60 obesity-related comorbidity) were treated in the Obesity Unit of Pitié-Salpetrière Hospital,

61 Institute of Cardio-metabolism and Nutrition, ICAN, Paris, France. Patients determined the

62 choice of technique, and advised by a multidisciplinary panel, from the hospital based on

63 medical history, level of corpulence and obesity-related comorbidity. Weight stable patients

64 were enrolled consecutively in this prospective non-randomized study from January 2012.

65 Hotel-Dieu hospital ethics committee approved the clinical protocol (number P100503 –

66 IDRCB 2011-A00759-32) which was recorded on clinical trial website (NCT:

67 NCT01655017). Subjects gave their written informed consent prior to the study inclusion.

68   Medical history and clinical evaluation were obtained at baseline and during the

69 follow-up at three (T3), six (T6) and twelve months (T12) as described elsewhere [21].

70 Anthropometric parameters were estimated by whole-body fan-beam DXA scanning (Hologic

71 Discovery W, software v12.6, 2; Hologic, Bedford, MA), as previously described [22].

72 Variables from DXA used in the analyses were total and appendicular fat free mass (FFM, in

73 kg), and total and appendicular fat mass (FM, in kg), where appendicular FFM (or FM) was

74 calculated as the sum of FFM (or FM) from both arms and both legs. Basal metabolic rate

4

(BMR) was assessed with indirect calorimetry (Deltatrac II monitor, Datex Instrumentarium

76 Corp., Helsinki, Finland) enabling the evaluation of underreporting of dietary intake [23].

77

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 $4\times100,000$ 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].

5

Nutrient adequacy of the diet

Nutrient intake adequacy for each patient was calculated using the PANDiet index [30]. Briefly, probability of adequacy for each nutrient was calculated, ranging from 0 to 1, where 1 represents a 100% probability that the usual intake is adequate (i.e. it satisfies the requirement or is not excessive compared to a reference value). According to this definition, the probabilities of adequacy were computed to obtain the Adequacy sub-score (the higher, the better the intake satisfies the nutrient requirements) and the Moderation sub-score (the higher, the less likely the intake is excessive). The PANDiet score is taken as the mean of the Adequacy and Moderation sub-scores, and ranges from 0 to 100; the higher the score, the better the nutrient adequacy of the diet. As reference values, we used French nutritional recommendations for healthy adults or European Union values when specific recommendations were lacking.

Biochemical analyses

Blood samples were collected after an overnight fast to measure biochemical parameters using routine techniques as described [31]. Blood count and iron metabolism markers (i.e. ferritin, iron, transferrin, and saturation coefficient) were assessed using routine care method (nephelemetry, ferrozine colorimetry and immunoturbidimetry respectively). Prealbumin was assessed by immunoturbidimetry. Serum concentrations of 25(OH)-vitamin-D3 and parathyroid hormone (PTH) were measured by chemiluminescent assay (310600 Liaison XL Diasorin and 11972103 Modular E 170 Roche, respectively), vitamin B-12 and folate were assessed using immunoanalysis ECL sandwich, and thiamin and vitamin B-6 were assessed using HPLC [6]. Vitamin and mineral deficiencies were defined as a result below the lower normal value given by the manufacturer [32]. Secondary hyperparathyroidism was

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).

128

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).

141

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).

160

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%

8

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).

180

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

9

199 increase in food intake, they remained below the baseline values (except for protein in the

200 GBP group, Table 3).

201

Nutritional deficiencies

203 At baseline, none of the metabolic and nutritional parameters were different between

204 the two groups (Table 4). As expected in severe obesity, 100% and 83% of the patients from

205 the GBP and SG groups, respectively, presented 25(OH)-vitamin-D3 deficiency as seen by

206 serum concentrations below 30 ng/ml (Table 4) with subsequent secondary

207 hyperparathyroidism in 50% of the subjects, showing major deficiency in this population.

208 After both BS, prealbumin concentration drastically and significantly decreased at T3

209 and further stabilized at T6 and T12 (Table 4). At T12, 38% of GBP patients and 52% of SG

210 patients presented mild protein depletion as shown by prealbumin concentration below the

211 normal range of 0.2 g/l and 21% of GBP patients and 16% of SG patients presented risk of

212 mild protein malnutrition as shown by albumin concentration below the normal value of 37

213 g/l (Table 4). Of note, two patients in the GBP group and one patient in the SG group

214 presented both mild protein depletion and risk of mild protein malnutrition. After both BS,

215 vitamin D supplementation enabled a significant increase in 25(OH)-vitamin-D3 serum

216 concentrations at T6, which stabilized at T12 (Table 4). However, 50% and 21% of GBP and

217 SG patients, respectively, still displayed secondary hyperparathyroidism at T12 (Table 4).

218 Since all patients were prescribed multivitamin and mineral supplementation, we verified

219 whether this supplementation might induce serum concentrations of selected vitamins and

220 minerals above the normal range at T12. In fact, there were only a few such cases in the

221 overall cohort: one with elevated serum thiamin (700 nmol/l) and one with high serum ferritin

222 (740 μg/l) in the SG group, and one with elevated vitamin B12 (580 pmol/l) in the GBP

223 group. Importantly, all such elevations remained below toxic levels.

224

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

11

249 follow-up period in both models. Appendicular FFM represents a better surrogate of muscle

250 mass than total FFM [37], and this is the first time that this outcome and its evolution have

251 been studied after SG. Interestingly, the change in appendicular FFM was similar in the two

252 surgical procedures.

253 After both BS, we observed that 61% of the patients reported daily protein

254 consumption under the recommended value of 60 g/day at T12 (64% for GBP and 58% for

255 SG). Our results are consistent with those of Andreu *et al.* and Moizé *et al.* who found that

256 respectively 37% and 46% of patients had a daily protein intake below 60 g/day one year after

257 BS [19,38]. In accordance with those findings, we did not find any difference between GBP

258 and SG [38]. We report a prevalence of insufficient protein intake that is nearly 2-fold higher

259 than that reported by Moizé *et al.* (61% versus 37%), which is mostly attributable to the

260 systematic protein supplementation prescribed by these authors to all of their patients [38].

261 One objective of recommending a minimal protein intake of 60 g/day after both GBP and SG

262 is to mitigate post-surgical FFM loss in the first months [17]. Indeed, Moizé *et al.*

263 demonstrated that patients with insufficient protein intake during the follow-up lost more

264 FFM in both SG and GBP than patients with sufficient protein intake [19]. Because skeletal

265 muscle is the primary site of insulin-stimulated glucose disposal during euglycemia [39], loss

266 of FFM might contribute to the development of insulin resistance and should be avoided in

267 order to maintain the beneficial metabolic outcomes. An important goal of future long-term

268 follow-up studies will be to determine whether insufficient protein intake following BS might

269 result in loss of muscular strength. Furthermore, longer-term weight stabilization (and regain)

270 should also be assessed in link with the quantity of protein intake.

271 After both BS, we also observed that prealbumin concentration significantly

272 decreased, resulting in more than a third of patients exhibiting mild protein depletion. Our

273 results are in line with the few studies that reported changes in prealbumin concentration after

12

274 GBP or SG. All studies found lower values at T12 after GBP compared to baseline

275 [15,40,41]. Results with SG are more heterogeneous, with reports showing both lower [42] or

276 no change in prealbumin concentrations [15,41]. Of note, Moizé *et al.* reported that 14% of

277 GBP and 16% of SG patients experienced abnormalities in prealbumin concentrations at T12

278 after BS [14]. As mentioned above, this difference may be due to the systematic prescription

279 of protein supplement in the Hospital Clinic of Barcelona [19,38]. Adequate protein intake

280 after BS is of utmost importance to prevent the patients from experiencing hair loss, poor

281 wound healing and adverse effects such as infections after skin repair surgery and ultimately –

282 but rarely – protein-calorie malnutrition [43,44].

283 Although SG merely restricts the volume of the stomach without intestinal

284 malabsorption [5], it also leads to an accelerated gastric emptying. Subsequently faster

285 gastrointestinal passage might promote nutrient deficiencies [45], as observed in a recent

286 study with increased faecal excretion of fatty acids [46], resulting in a state of moderate

287 malabsorption. Furthermore, SG decreases gastric intrinsic factor and gastric acid production,

288 two factors involved in vitamin B-12 and iron absorption. Because most of our patients took

289 the prescribed daily multivitamin and mineral supplements one year after both GBP and SG,

290 few patients experienced nutritional abnormalities (except for 25(OH)-vitamin-D3) and there

291 was no difference between the two surgical groups. Our results were consistent with previous

292 data from the literature [14,15]. Conversely, others reported a higher risk of vitamin B-12 and

293 25(OH)-vitamin-D3 deficiencies after GBP compared to SG [12]. It should be noted that in

294 these three studies, patients undergoing GBP or SG were instructed to take multivitamin and

295 mineral supplements on a daily basis after BS. Another point to take into account, is the risk

296 of developing undesirably high levels of micronutrient concentrations due to the systematic

297 supplementation as was previously reported after SG [7,8,11]. Herein, we only identified one

298 patient with serum thiamin and another with serum ferritin above normal range. Nevertheless,

13

299 it should be noted that the risk of excessive levels in those studies were mostly observed for

300 vitamin A and B-6, which we did not assess. Altogether, these data highlight the importance

301 to prescribe daily multivitamin and mineral supplements after both GBP and SG at least in the

302 first year, but also to monitor the adherence of the patients to their supplementation.

303 At baseline, the higher prevalence of glucose intolerance in patients undergoing GBP

304 reflects the process of selection for different BS techniques, where GBP is the first choice for

305 patients with T2D or glucose intolerance since it demonstrated its superiority over SG to

306 improve glycemic status post-surgery [35]. We also observed that neither GBP nor SG

307 enabled a significant improvement of HBP in terms of overall prevalence. Nevertheless, both

308 the number of patients treated and the number of treatments per patients tended to decrease

309 after both surgeries, suggesting slight improvement of HBP in this cohort of obese patients

310 with many comorbidities. Nevertheless our data are in accordance with previous studies,

311 which indicated that HBP may not be the best resolved comorbidity after surgery [47,48].

312 One of the main strengths of our study is the use of a validated web-based method of

313 dietary assessment which allowed us to provide detailed quantification of the food and

314 nutrient intake for each patient [24]. This method allows us to assess the use of multivitamin

315 and mineral supplements and measure adherence of the patients to the supplementation.

316 Although the interventions were not randomized in our study, our participants had

317 comparable clinical characteristics at baseline (except for T2D) and were provided the same

318 systematic supplementation regardless of the surgical procedure. The main limitation

319 concerns the relative small number of patients, especially in the group who completed the one

320 year follow-up. This may have prevented us from detecting changes between FFM loss and

321 low protein intake after both procedures. Future studies with longer follow-up periods and

322 larger sample size are needed to determine how poor dietary habits and nutritional

323 deficiencies correlate with weight maintenance at longer term and with the improvement or

324 resolution of obesity related co-morbidities. We intend to follow this cohort in the second

325 year of their surgery to assess their evolution in terms of nutritional risks and body

326 composition.

327   In conclusion, we observed similar food restriction effects on the nutritional adequacy

328 of the diet in the first year post GBP and SG surgery. We also observed comparable

329 consequences in terms of bioclinical evolution and micronutrient serum concentrations.

330 Altogether, our results advocate for a cautious monitoring of protein intake and a systematic

331 multivitamin and mineral supplementation after both GPB and SG – at least in the first year

332 for SG.

333

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

REFERENCES

1. Buchwald H, Avidor Y, Braunwald E, et al. Bariatric surgery: a systematic review and meta-analysis. JAMA. 2004 Oct 13;292(14):1724–37.

2. Mingrone G, Panunzi S, De Gaetano A, et al. Bariatric surgery versus conventional medical therapy for type 2 diabetes. N Engl J Med. 2012 Apr 26;366(17):1577–85.

3. Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2011. Obes Surg. 2013 Apr;23(4):427–36.

4. Chang S-H, Stoll CRT, Song J, et al. The effectiveness and risks of bariatric surgery: an updated systematic review and meta-analysis, 2003-2012. JAMA Surg. 2014 Mar;149(3):275–87.

5. Jacobs M, Bisland W, Gomez E, et al. Laparoscopic sleeve gastrectomy: a retrospective review of 1- and 2-year results. Surg Endosc. 2009 Aug 19;24(4):781–5.

6. Aasheim ET, Hofsø D, Hjelmesaeth J, et al. Vitamin status in morbidly obese patients: a cross-sectional study. Am J Clin Nutr. 2008 Feb;87(2):362–9.

7. Aarts EO, Janssen IMC, Berends FJ. The gastric sleeve: losing weight as fast as micronutrients? Obes Surg. 2011 Feb;21(2):207–11.

8. Damms-Machado A, Friedrich A, Kramer KM, et al. Pre- and postoperative nutritional deficiencies in obese patients undergoing laparoscopic sleeve gastrectomy. Obes Surg. 2012 Jun;22(6):881–9.

9. Pech N, Meyer F, Lippert H, et al. Complications and nutrient deficiencies two years after sleeve gastrectomy. BMC Surg. 2012;12:13.

10. Saif T, Strain GW, Dakin G, et al. Evaluation of nutrient status after laparoscopic sleeve gastrectomy 1, 3, and 5 years after surgery. Surg Obes Relat Dis Off J Am Soc Bariatr Surg. 2012 Oct;8(5):542–7.

16

11. Van Rutte PWJ, Aarts EO, Smulders JF, et al. Nutrient deficiencies before and after sleeve gastrectomy. Obes Surg. 2014 Oct;24(10):1639–46.

12. Gehrer S, Kern B, Peters T, et al. Fewer nutrient deficiencies after laparoscopic sleeve gastrectomy (LSG) than after laparoscopic Roux-Y-gastric bypass (LRYGB)-a prospective study. Obes Surg. 2010 Apr;20(4):447–53.

13. Kehagias I, Karamanakos SN, Argentou M, et al. Randomized clinical trial of laparoscopic Roux-en-Y gastric bypass versus laparoscopic sleeve gastrectomy for the management of patients with BMI $<$ 50 kg/m2. Obes Surg. 2011 Nov;21(11):1650–6.

14. Moizé V, Andreu A, Flores L, et al. Long-term dietary intake and nutritional deficiencies following sleeve gastrectomy or Roux-En-Y gastric bypass in a mediterranean population. J Acad Nutr Diet. 2013 Mar;113(3):400–10.

15. Coupaye M, Rivière P, Breuil MC, et al. Comparison of nutritional status during the first year after sleeve gastrectomy and Roux-en-Y gastric bypass. Obes Surg. 2014 Feb;24(2):276–83.

16. Kwon Y, Kim HJ, Lo Menzo E, et al. Anemia, iron and vitamin B12 deficiencies after sleeve gastrectomy compared to Roux-en-Y gastric bypass: a meta-analysis. Surg Obes Relat Dis Off J Am Soc Bariatr Surg. 2014 Aug;10(4):589–97.

17. Mechanick JI, Youdim A, Jones DB, et al. Clinical Practice Guidelines for the Perioperative Nutritional, Metabolic, and Nonsurgical Support of the Bariatric Surgery Patient - 2013 Update: Cosponsored by American Association of Clinical Endocrinologists, The Obesity Society, and American Society for Metabolic & Bariatric Surgery. Obes Silver Spring Md. 2013 Mar;21(0 1):S1–27.

18. Freeman RA, Overs SE, Zarshenas N, et al. Food tolerance and diet quality following adjustable gastric banding, sleeve gastrectomy and Roux-en-Y gastric bypass. Obes Res Clin Pract. 2014 Apr;8(2):e115–200.

19. Moizé V, Andreu A, Rodríguez L, et al. Protein intake and lean tissue mass retention following bariatric surgery. Clin Nutr Edinb Scotl. 2013 Aug;32(4):550–5.

20. Fried M, Yumuk V, Oppert J-M, et al. Interdisciplinary European Guidelines on metabolic and bariatric surgery. Obes Facts. 2013;6(5):449–68.

21. Abdennour M, Reggio S, Le Naour G, et al. Association of adipose tissue and liver fibrosis with tissue stiffness in morbid obesity: links with diabetes and BMI loss after gastric bypass. J Clin Endocrinol Metab. 2014 Mar;99(3):898–907.

22. Ciangura C, Bouillot J-L, Lloret-Linares C, et al. Dynamics of change in total and regional body composition after gastric bypass in obese patients. Obes Silver Spring Md. 2010 Apr;18(4):760–5.

23. Nielsen BM, Nielsen MM, Toubro S, et al. Past and current body size affect validity of reported energy intake among middle-aged Danish men. J Nutr. 2009 Dec;139(12):2337–43.

24. Touvier M, Kesse-Guyot E, Méjean C, et al. Comparison between an interactive web-based self-administered 24 h dietary record and an interview by a dietitian for large-scale epidemiological studies. Br J Nutr. 2011 Apr;105(7):1055–64.

25. Le Moullec N, Deheeger M, Preziosi P, et al. Validation du manuel-photos utilisé pour l'enquête alimentaire de l'étude SU.VI.MAX. Cah Nutr Diététique. 31(3):158–64.

26. Gesquiere I, Aron-Wisnewsky J, Foulon V, et al. Medication cost is significantly reduced after Roux-en-Y gastric bypass in obese patients. Obes Surg. 2014 Nov;24(11):1896–903.

27. Afssa - Table de composition nutritionnelle des aliments CIQUAL 2008 (French Food Composition Table – CIQUAL 2008). Available from: https://pro.anses.fr/tableciqual/index.htm.

28. Hercberg S, Chat-Yung S, Chaulia M. The French National Nutrition and Health Program: 2001-2006-2010. Int J Public Health. 2008;53(2):68–77.

29. Estaquio C, Kesse-Guyot E, Deschamps V, et al. Adherence to the French Programme National Nutrition Santé Guideline Score is associated with better nutrient intake and nutritional status. J Am Diet Assoc. 2009 Jun;109(6):1031–41.

30. Verger EO, Mariotti F, Holmes BA, et al. Evaluation of a diet quality index based on the probability of adequate nutrient intake (PANDiet) using national French and US dietary surveys. PloS One. 2012;7(8):e42155.

31. Aron-Wisnewsky J, Minville C, Tordjman J, et al. Chronic intermittent hypoxia is a major trigger for non-alcoholic fatty liver disease in morbid obese. J Hepatol. 2012 Jan;56(1):225–33.

32. Ledoux S, Msika S, Moussa F, et al. Comparison of nutritional consequences of conventional therapy of obesity, adjustable gastric banding, and gastric bypass. Obes Surg. 2006 Aug;16(8):1041–9.

33. Hutter MM, Schirmer BD, Jones DB, et al. First report from the American College of Surgeons Bariatric Surgery Center Network: laparoscopic sleeve gastrectomy has morbidity and effectiveness positioned between the band and the bypass. Ann Surg. 2011 Sep;254(3):410–420; discussion 420–422.

34. Lim DM, Taller J, Bertucci W, et al. Comparison of laparoscopic sleeve gastrectomy to laparoscopic Roux-en-Y gastric bypass for morbid obesity in a military institution. Surg Obes Relat Dis Off J Am Soc Bariatr Surg. 2014 Apr;10(2):269–76.

35. Kashyap SR, Bhatt DL, Wolski K, et al. Metabolic effects of bariatric surgery in patients with moderate obesity and type 2 diabetes: analysis of a randomized control trial comparing surgery with intensive medical treatment. Diabetes Care. 2013 Aug;36(8):2175–82.

36. Bužga M, Zavadilová V, Holéczy P, et al. Dietary intake and ghrelin and leptin changes after sleeve gastrectomy. Videosurgery Miniinvasive Tech. 2014 Dec;9(4):554–61.

37. Kim J, Wang Z, Heymsfield SB, et al. Total-body skeletal muscle mass: estimation by a new dual-energy X-ray absorptiometry method. Am J Clin Nutr. 2002 Aug 1;76(2):378–83.

38. Andreu A, Moizé V, Rodríguez L, et al. Protein intake, body composition, and protein status following bariatric surgery. Obes Surg. 2010 Nov;20(11):1509–15.

39. DeFronzo RA, Jacot E, Jequier E, et al. The effect of insulin on the disposal of intravenous glucose. Results from indirect calorimetry and hepatic and femoral venous catheterization. Diabetes. 1981 Dec;30(12):1000–7.

40. Coupaye M, Puchaux K, Bogard C, et al. Nutritional consequences of adjustable gastric banding and gastric bypass: a 1-year prospective study. Obes Surg. 2009 Jan;19(1):56–65.

41. Sallé A, Demarsy D, Poirier AL, et al. Zinc deficiency: a frequent and underestimated complication after bariatric surgery. Obes Surg. 2010 Dec;20(12):1660–70.

42. Friedrich AE, Damms-Machado A, Meile T, et al. Laparoscopic sleeve gastrectomy compared to a multidisciplinary weight loss program for obesity--effects on body composition and protein status. Obes Surg. 2013 Dec;23(12):1957–65.

43. Agha-Mohammadi S, Hurwitz DJ. Nutritional deficiency of post-bariatric surgery body contouring patients: what every plastic surgeon should know. Plast Reconstr Surg. 2008 Aug;122(2):604-13.

44. Faria SL, Faria OP, Buffington C, de Almeida Cardeal M, Ito MK. Dietary protein intake and bariatric surgery patients: a review. Obes Surg. 2011 Nov;21(11):1798–805.

45. Melissas J, Daskalakis M, Koukouraki S, et al. Sleeve Gastrectomy - A "Food Limiting" Operation. Obes Surg. 2008 Jul 29;18(10):1251–6.

46. Damms-Machado A, Mitra S, Schollenberger AE, et al. Effects of Surgical and Dietary Weight Loss Therapy for Obesity on Gut Microbiota Composition and Nutrient Absorption. BioMed Res Int. 2015 Feb 1;2015:e806248.

47. Sjöström L, Narbro K, Sjöström CD, et al. Effects of bariatric surgery on mortality in Swedish obese subjects. Engl J Med. 2007 Aug 23;357(8):741-52.

48. Gesquiere I, Aron-Wisnewsky J, Foulon V, et al. Medication cost is significantly reduced after Roux-en-Y gastric bypass in obese patients. Obes Surg. 2014 Nov;24(11):1896-903.

TABLES

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

	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/m²*	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	59.9d	50.9^a	53.1^b	56.3^c	54.9^c
Fat mass (%)	45.8^d	43.2^c	39.4^b	36.9a	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)

[1]Labeled 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.)*

TABLE 2. Energy, food and macronutrient intakes according to the surgical models at baseline, 3 months and 12 months[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
Energy and food intakes						
Energy intake, *kcal/d*	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, *kcal/d*	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, *serving/d*	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, *serving/d*	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, *serving/d*	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, *serving/d*	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, *g/d*	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, *g/kg/d*	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, *%EI/d*	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, *%EI/d*	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, *%EI/d*	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, *%EI/d*	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)

[1]Labeled 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 3. Multivitamin and mineral supplementation, PANDiet scores and probabilities of nutrient adequacy according to the surgical models at baseline, 3 months and 12 months[1]

	GBP			SG		
	Baseline	3 months	12 months	Baseline	3 months	12 months
	n=22	n=22	n=14	n=30	n=30	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)

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)

[1]Labeled 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.

25

TABLE 4. Metabolic and nutritional parameters according the surgical models at baseline, 3 months, 6 months and 12 months[1]

	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 (130-19.0)
<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)

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)

[1]Labeled 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 ± 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]
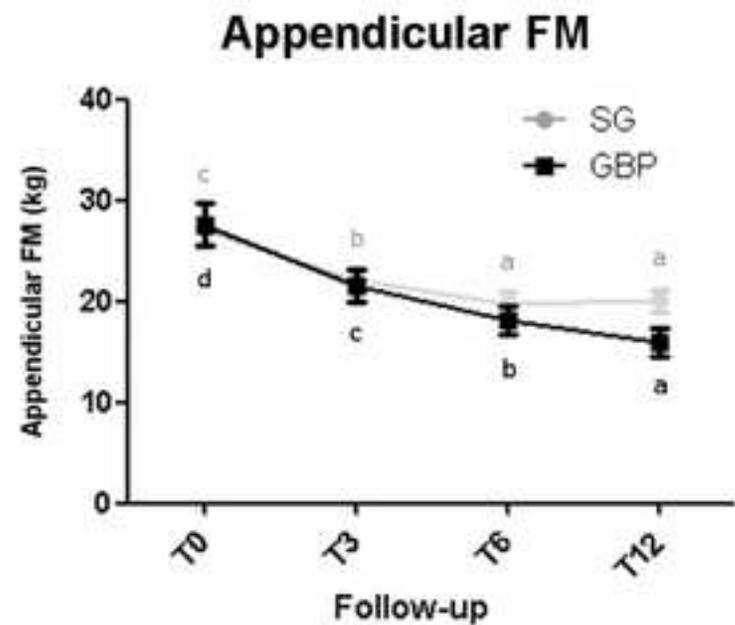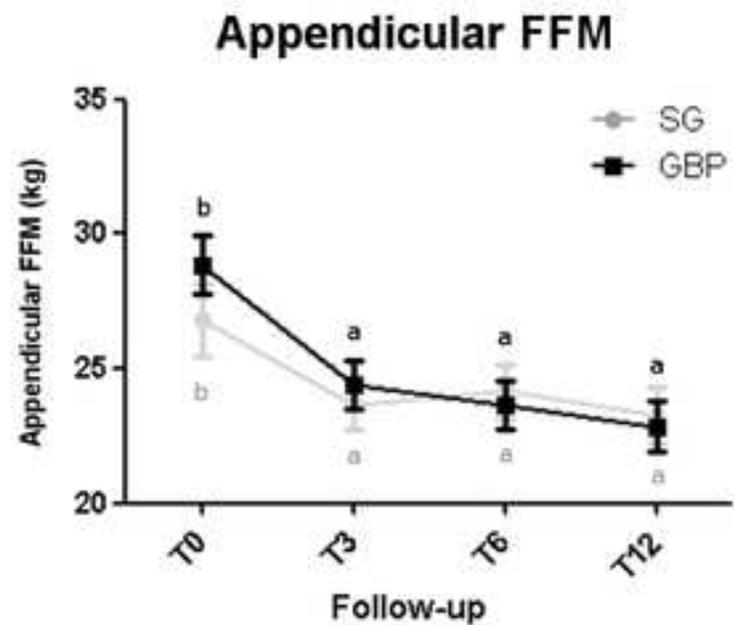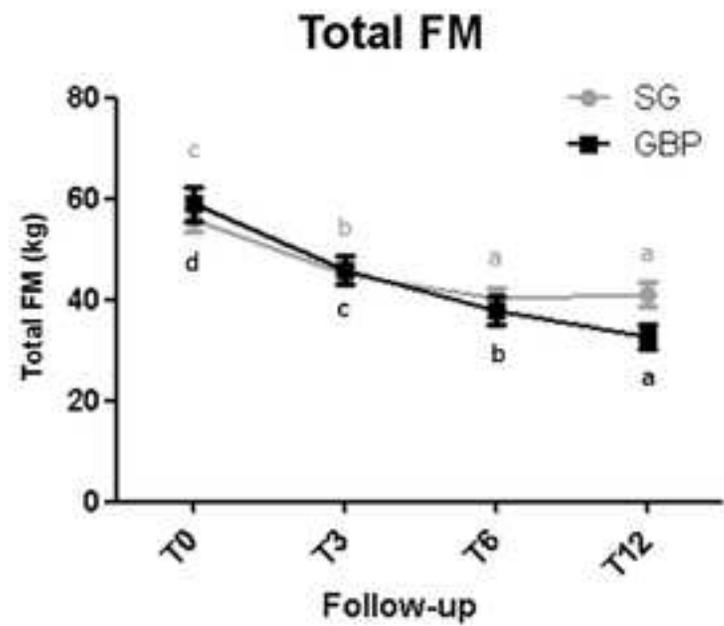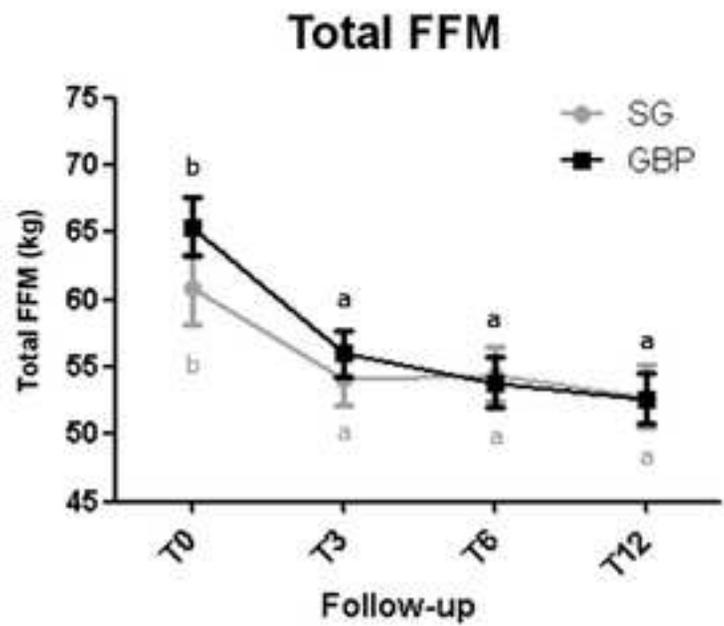
	GBP			SG		
	Baseline	3 months	12 months	Baseline	3 months	12 months
	n=22	n=22	n=14	n=30	n=30	n=19
PANDiet	66.0 (60.7-70.5)[b]	51.6 (47.8-53.7)[a]	52.1 (46.1-57.6)[a]	57.7 (54.0-62.1)[b]	47.6 (40.9-53.0)[a]	52.9 (46.7-60.6)[b]
Moderation Sub-score	64.6 (58.6-85.6)	82.1 (75.6-85.3)	74.3 (61.8-81.2)	63.2 (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 (.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	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]

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]

[1]Labeled 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

Total FFM

Total FM

Appendicular FFM

Appendicular FM