Obesity Surgery (2019) 29:3589–3595
https://doi.org/10.1007/s11695-019-04037-6

ORIGINAL CONTRIBUTIONS

# Changes in Body Composition, Comorbidities, and Nutritional Status Associated with Lower Weight Loss After Bariatric Surgery in Older Subjects

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Published online: 25 June 2019


## Abstract

**Background** To provide greater insight into bariatric surgery outcomes in aging patients, we compared changes in body weight, body composition, obesity-related comorbidities, and nutritional status between older and younger subjects.

**Methods** We analyzed data collected between January 2004 and December 2014 from our prospective bariatric cohort. Older patients (OP, ≥ 60 years at the time of surgery, $n = 93$; 66% Roux-en-Y gastric bypass, 34% sleeve gastrectomy) were compared with younger patients (YP, < 60 years, $n = 186$), matched 1:2 on sex, body mass index, diabetes, and surgical procedure. Body composition was assessed by dual-energy X-ray absorptiometry.

**Results** Weight loss and excess weight loss at 12 months were lower in OP vs. YP (mean ± SD, 30.1 ± 10.1 vs. 34.1 ± 11.9 kg, 60.6 ± 21.2 vs. 66.8 ± 23.4%, respectively, $p < 0.05$ for both). Both lean body mass and fat mass loss were lower in OP vs. YP (8.4 ± 3.4 vs. 9.2 ± 9.0 kg, 19.4 ± 8.7 vs. 21.9 ± 9.1 kg, respectively, $p < 0.05$). The remission rate for type 2 diabetes was significantly lower in OP vs. YP (24 vs. 45%), as well as improvement in hypertension (14 vs. 46%), dyslipidemia (27 vs. 47%), and knee pain. There was no difference in micronutrient deficiencies between groups.

**Conclusions** These data indicate that although bariatric surgery is not as effective for weight loss in older as in younger subjects, it is a safe option regarding a comprehensive set of nutritional variables which enables significant improvement in obesity-related outcomes.

**Keywords** Elderly · Bariatric surgery · Body composition · Comorbidities · Obesity

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## Introduction

Life expectancy is increasing in most countries, and by 2050, the number of US older adults is expected to more than double, rising from 40.2 million to 88.5 million [1]. Recent data show that US adults aged ≥ 60 years have obesity rates exceeding 37.5% in men and 39.4% in women, compared to 34.3% in adults < 40 years old [1]. Similar figures have been reported in other industrialized countries such as France where the prevalence of obesity in 2012 was 18.7% and 10.2% in adults over and below 45 years, respectively [2]. Obesity is associated with decreased life expectancy and quality of life and is thus a serious concern in older subjects [3, 4]. Nutritional management and obesity care in this age group have specific challenges including prevention of muscle loss and sarcopenia, and prevention of functional impairments that can lead to disability [3, 4].

The effectiveness and safety of bariatric surgery in older subjects remain a matter of debate [5]. There is some evidence in the literature suggesting lower body weight loss in older subjects [6–11]. However, a recent systematic review [5], based on 26 studies and more than 8000 patients, emphasized the limits of the available data including a paucity of well-reported studies, heterogeneous age cut-offs to define older subjects, and small sample size in most studies [5]. Moreover, none of the previous studies performed a detailed assessment of changes in body composition after bariatric surgery in older subjects.

Our objectives were to compare changes after bariatric surgery in body weight, body composition, energy expenditure, obesity-related comorbidities, and nutritional status as well as surgical complications between subjects over 60 years and younger subjects carefully matched on sex, body mass index (BMI), preoperative diabetes status, and type of surgical procedure.

## Material and Methods

### Patients

We retrospectively reviewed data from our ongoing bariatric cohort (Bariatric Surgery Cohort of the Institute of Cardiometabolism and Nutrition [BARICAN]) that prospectively includes all patients undergoing either laparoscopic Roux-en-Y gastric bypass (LRYGB) or sleeve gastrectomy (SG) at our center between January 2004 and December 2015. Our standardized protocol for management of these patients includes assessment of body composition by dual-energy X-ray absorptiometry (DXA) before and 3, 6, and 12 months after surgery. The database is registered with the French National Data Protection Agency (CNIL, #1689730).

Among 1661 patients in our database, we first excluded patients with type 1 diabetes ($n = 12$), or aged < 18 years ($n = 7$), or patients who had another type of surgery than LRYGB or SG or a history of previous bariatric surgery ($n = 167$). We identified 156 older patients, including 93 older patients (OP) with complete 12-month follow-up records including body composition data representing the sample analyzed in this paper. When comparing older subjects with complete DXA data ($n = 93$) to those with missing DXA ($n = 63$), the latter had higher baseline body weight and BMI, but not significantly different values for age, gender ratio, type of surgery, initial fat mass (kg), body weight loss, and initial and post-operative data for obesity-related comorbidities (data not shown). It is known that some patients above a certain weight limit (i.e., 160–180 kg) or with large transversal corpulence cannot access DXA scan [12].

OP ($n = 93$) were then individually matched 1:2 for sex, BMI (±2 kg/m$^2$), preoperative diabetes status, and type of surgical procedure (either LRYGB or SG), with young patients (YP; preoperative age < 60 y)) ($n = 186$). Type 2 diabetes was defined as fasting blood glucose ≥ 7 mmol/L or glycated hemoglobin (HbA1c) > 6.5% or the use of oral antidiabetic drugs, insulin, or GLP-1 analogues.

The study was approved by the local ethics committee. Bariatric surgery was offered to patients in accordance with French guidelines [13], which are similar to those of the US National Institutes of Health [14], and was performed as previously reported [15]. General dietary and physical activity counseling, vitamin and mineral supplementation, and medical follow-up were provided to all participants during planned pre- and post-surgery visits at 3, 6, and 12 months, as part of usual care [16] and according to guidelines [17, 18]. Body weight, body composition, and resting energy expenditure (REE) were measured before and at 3 (except for REE), 6, and 12 months after surgery. Biological parameters and obesity comorbidities were recorded before and 12 months after surgery.

### Body Weight, Body Composition, and Energy Expenditure

Body composition was estimated by whole-body fan-beam DXA scanning (Hologic Discovery W, software v12.6, 2; Hologic, Bedford, MA) [12], and variables used in the analyses were total and appendicular lean body mass (LBM, kg), and total and trunk fat mass (FM, kg). Appendicular LBM was calculated as the sum of LBM from arms and legs. LBM, either total or appendicular, was bone-free lean soft tissue. Weight loss was expressed as change in weight (kg), total weight loss (%TWL), and excess weight loss (%EWL), with the calculation of ideal body weight as that equivalent to a BMI of 25 kg/m$^2$. REE was measured by indirect calorimetry using an open-circuit ventilated-hood system (Deltatrac II monitor, Datex Instrumentarium Corp., Helsinki, Finland) [19].

### Biological Parameters

Blood samples were collected after an overnight fast to measure routine parameters (blood count, blood glucose, albumin, transthyretin, 25(OH) vitamin D3, vitamin B12, folate, thiamine). Hypoalbuminemia, low transthyretin, vitamin, and mineral deficiencies were defined as a result below the lower normal value given by the manufacturer; secondary hyperparathyroidism was defined as an elevated PTH above the high normal laboratory value [20]. Malnutrition was defined by albumin < 35 g/L or transthyretin < 0.11 g/L in patients aged > 70 years, and by albumin < 30 g/L or transthyretin < 0.11 g/L in patients aged ≤ 70 years [21, 22].

### Obesity-Related Comorbidities and Complications of Surgery

Obesity-related comorbidities were defined through detailed assessment of each medical record including medical history and medication use [23]. Resolution of hypertension, dyslipidemia, and obstructive sleep apnea (OSA) syndrome was defined as normalization of the corresponding characteristics without treatment. Diabetes resolution was defined according to the American Diabetes Association (ADA) criteria of total remission: no antidiabetic drug, fasting blood glucose < 5.6 mmol/L, and glycated hemoglobin (HbA1c) < 6.0% [24]. Addiarem [25] and Diarem [26] scores were used to assess prediction of diabetes remission after bariatric surgery. The rate of early (within 30 days after surgery) as well as later complications was recorded prospectively in the database.

### Statistical Analyses

Data are presented as means ± SD for continuous variables and as frequencies and percentages for categorical variables. Two-level ANOVA for repeated measures was used to compare means of continuous variables between age groups before and during 1-year follow-up after bariatric surgery. When the ANOVA procedure revealed significant differences, Bonferroni multiple tests were used for post hoc comparisons. A $\chi^2$ test was used to compare changes in categorical variables between age groups before and 1 year after surgery. $p < 0.05$ was considered significant. Analyses were performed using NCSS 10 Statistical Software (NCSS, LLC. Kaysville, Utah).

## Results

Regarding baseline characteristics, the mean age was 63.7 ± 2.7 years in OP and 42.6 ± 9.7 years in YP (Table 1). As expected given the study design, no significant difference was found between the 2 groups for female ratio (77%), type of surgery (66% underwent LRYGB and 34% SG), BMI, and diabetes status (69% with type 2 diabetes). A significant difference was found for weight, LBM, REE (lower in OP), and obesity-related comorbidities (higher in OP).

Regarding post-operative changes, compared with YP, OP subjects displayed lower weight and FM loss and LBM loss, when expressed in absolute values (kg) (Table 2). Although baseline total LBM (kg) was lower in OP compared to YP, LBM loss expressed as percentage of weight loss was not different between groups. Regarding regional body composition, changes in appendicular LBM (kg) and trunk FM (kg) did not differ between groups. Even though initial measured REE was lower in OP in parallel with lower LBM, there was no significant difference between groups for REE (kcal/day)

**Table 1** Baseline characteristics of the two age groups over and below age 60 years before bariatric surgery

| | Older patients ≥ 60 years | Younger patients 18–59 years |
|---|---|---|
| *n* | 93 | 186 |
| ….bypass, *n* (%) | 61 (66%) | 122 (66%) |
| ….sleeve, *n* (%) | 32 (34%) | 64 (34%) |
| Age, mean ± SD | 63.7 ± 2.7 | 42.6 ± 9.7* |
| Gender (% women) | 77 | 77 |
| Weight (kg), mean ± SD | 118.6 ± 16.2 | 122.9 ± 18.8* |
| Height (cm), mean ± SD | 163.2 ± 8.2 | 166.5 ± 9.0* |
| BMI (kg/m$^2$), mean ± SD | 44.5 ± 5.1 | 44.2 ± 5.4 |
| Excess weight (kg), mean ± SD | 51.9 ± 13.5 | 53.3 ± 15.2 |
| LBM (kg), mean ± SD | 58.6 ± 9.4 | 61.4 ± 10.9* |
| FM (kg), mean ± SD | 55.9 ± 9.8 | 56.4 ± 11.1 |
| Percent body fat (%) | 47.7 ± 5.0 | 46.6 ± 5.3 |
| REE (kcal/day), mean ± SD | 1928 ± 31 | 2103 ± 409* |
| REE/LBM (kcal/d/kg), mean ± SD | 34.5 ± 1.4 | 33.3 ± 1.3* |
| Diabetes (% yes) | 69 | 69 |
| Dyslipidemia (% yes) | 85 | 86 |
| Hypertension (% yes) | 78 | 56* |
| Obstructive sleep apnea (% yes) | 83 | 63* |
| Knee pain (% yes) | 71 | 60 |

*SD* standard deviation, *BMI* body mass index, *LBM* lean body mass, *FM* fat mass, *REE* resting energy expenditure

*$p < 0.05$ for comparison between age groups (Bonferroni test)

Younger patients were matched to older patients (2:1) for gender, initial BMI at ± 2 kg/m$^2$, presence of diabetes, and type of surgical procedure (see "Materials and Methods")

**Table 2** Post-operative changes in weight, excess weight loss, body mass index, and body composition in the two age groups

| | At 3 months | At 6 months | At 12 months |
|---|---|---|---|
| Weight loss (kg) | | | |
| OP | 18.1 ± 5.0*$^{A}$ | 24.8 ± 7.4*$^{B}$ | 30.1 ± 10.1*$^{C}$ |
| YP | 19.8 ± 6.4$^{A}$ | 28.3 ± 8.9$^{B}$ | 34.1 ± 11.9$^{C}$ |
| Total weight loss (%) | | | |
| OP | 15.4 ± 4.3$^{A}$ | 21.1 ± 5.9$^{B}$ | 25.5 ± 8.0$^{C}$ |
| YP | 16.1 ± 4.5$^{A}$ | 23.1 ± 6.2*$^{B}$ | 27.8 ± 8.5*$^{C}$ |
| Excess weight loss (%) | | | |
| OP | 37.1 ± 12.9$^{A}$ | 50.3 ± 17.1*$^{B}$ | 60.6 ± 21.2*$^{C}$ |
| YP | 38.9 ± 12.6$^{A}$ | 55.8 ± 17.9$^{B}$ | 66.8 ± 23.4$^{C}$ |
| BMI loss | | | |
| OP | 6.8 ± 1.9$^{A}$ | 9.3 ± 2.7*$^{B}$ | 11.3 ± 3.8*$^{C}$ |
| YP | 7.1 ± 2.3$^{A}$ | 10.0 ± 3.6$^{B}$ | 12.2 ± 4.1$^{C}$ |
| LBM loss (kg) | | | |
| OP | 6.5 ± 3.6$^{A}$ | 7.4 ± 3.5*$^{B}$ | 8.4 ± 3.4*$^{C}$ |
| YP | 7.1 ± 3.7$^{A}$ | 8.3 ± 3.9$^{B}$ | 9.2 ± 9.0$^{C}$ |
| LBM loss (% of weight loss) | | | |
| OP | 34.3 ± 18.2$^{A}$ | 29.7 ± 11.5$^{B}$ | 28.2 ± 11.7$^{B}$ |
| YP | 35.8 ± 15.5$^{A}$ | 29.2 ± 10.5$^{B}$ | 28.0 ± 10.2$^{B}$ |
| FM loss (kg) | | | |
| OP | 10.6 ± 3.3$^{A}$ | 15.6 ± 5.0*$^{B}$ | 19.4 ± 8.7*$^{C}$ |
| YP | 11.1 ± 5.1$^{A}$ | 17.8 ± 6.8$^{B}$ | 21.9 ± 9.1$^{C}$ |
| FM loss (% of weight loss) | | | |
| OP | 58.9 ± 16.9$^{A}$ | 64.0 ± 13.1$^{B}$ | 63.5 ± 17.0$^{B}$ |
| YP | 55.9 ± 21.6$^{A}$ | 63.0 ± 14.9$^{B}$ | 64.6 ± 12.7$^{B}$ |
| Appendicular LBM loss (kg) | | | |
| OP | 2.6 ± 2.7$^{A}$ | 2.9 ± 2.3$^{A}$ | 3.5 ± 2.3$^{B}$ |
| YP | 2.8 ± 2.8$^{A}$ | 3.4 ± 2.3$^{B}$ | 3.7 ± 2.4$^{B}$ |
| Trunk FM loss (kg) | | | |
| OP | 6.4 ± 3.6$^{A}$ | 9.1 ± 4.3*$^{B}$ | 11.5 ± 5.9*$^{C}$ |
| YP | 6.9 ± 3.7$^{A}$ | 10.5 ± 4.8$^{B}$ | 12.9 ± 5.9$^{C}$ |
| REE loss (kcal/day) | | | |
| OP | – | 300 ± 241*$^{A}$ | 302 ± 228*$^{A}$ |
| YP | – | 400 ± 270$^{A}$ | 451 ± 308$^{B}$ |
| REE/LBM loss (kcal/kg/day) | | | |
| OP | – | 1.1 ± 3.8*$^{A}$ | 0.6 ± 3.9*$^{A}$ |
| YP | – | 2.3 ± 3.8$^{A}$ | 2.5 ± 4.4$^{A}$ |

Data are expressed as mean ± standard deviation. Different letters represent significant difference ($p < 0.05$) between operative times in each age group compared to baseline (Bonferroni test)

*OP* older patients, *YP* younger patients, *BMI* body mass index, *LBM* lean body mass, *FM* fat mass, *REE* resting energy expenditure

*$p < 0.05$ for comparison between age groups (Bonferroni test)

at 12 months, as for REE/LBM (kcal/kg/day) as expected given the similar values for LBM at 12 months. When comparing older vs. younger patients separately for those undergoing either sleeve of bypass, results were similar to bypass and sleeve results together (data not shown).

Diarem and Addiarem scores were 8.9 ± 6.5 and 9.9 ± 5.8 in YP ($n = 128$ and 122 respectively) vs. 11.4 ± 6.7 and 13.4 ± 5.6 in OP ($n = 64$ and 63, respectively) ($p < 0.05$). The rate of remission of type 2 diabetes was significantly lower in OP vs. YP (24% vs. 45%), as were the rates of remission of dyslipidemia (27% vs. 47%), of hypertension (14% vs. 46%), and of knee pain (31% vs. 58%)." (Fig. 1).

There was no preoperative difference between groups in hypoalbuminemia (20% in YP and 22% in OP), low transthyretin (27% in YP and 19% in OP), malnutrition (0% in YP and 2% in OP), B12 deficiency, D deficiency, hyperparathyroidy, and in anemia. One year after surgery, iron deficiency was observed in 0% (0/45) of OP vs. 14% (16/115) of YP ($p = 0.001$), vitamin D deficiency in 50% (23/46) of OP vs. 67% (58/86) of YP ($p = 0.049$), and folate deficiency in 5% (2/42) of OP vs. 28% (22/78) of YP ($p = 0.002$) without any difference in B12 deficiency or in hyperparathyroidism or in anemia. No case of malnutrition was observed in YP compared to one case at baseline and two cases 1 year after surgery in OP. No death was reported after surgery in these patients. A non-significant increased rate of adverse events before 30 days was observed in YP vs. OP (23 vs. 15%). No difference in nonsurgical postoperative complications was observed (10% in the two groups).

## Discussion

In this study, we compared outcomes of bariatric surgery including DXA-assessed body composition and biological nutritional status in subjects over 60 years and younger subjects carefully matched on sex, BMI, diabetes status, and type of procedure. In OP vs. YP, we found lower weight loss, FM loss, and also LBM loss. Moreover, rates of resolution of obesity-related comorbidities were lower in OP vs. YP, whereas no significant difference was observed in changes in biological nutritional parameters and in the rate of post-surgery adverse events.

Lower weight loss in older subjects is in agreement with a number of previous studies [6–11, 27–32]. Although some studies observed no significant difference in weight loss with relation to age, these studies present with some important limitations: only one type of surgery such as sleeve gastrectomy was assessed [33–35], studies included only small samples [36], and none compared the outcomes to a younger population that had been appropriately matched on important baseline characteristics [6] such as diabetes status [37]. Our data, based on serial measurements of body weight and composition, showed that lower weight loss in OP vs. YP was a consistent trend over time, up to 12 months of follow-up. Noteworthily, the difference in weight loss was not of major magnitude compared to the overall post-surgery weight loss (4 kg difference between age groups on average, compared to

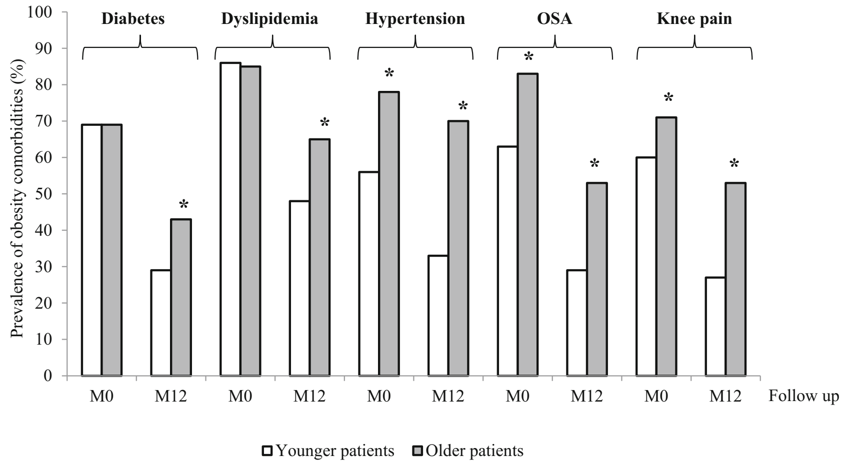


**Fig. 1** Prevalence of obesity comorbidities before and 1 year after surgery in the two age groups. Abbreviations: *M0* preoperative time; *M12* 12 months after surgery; *OSA* obstructive sleep apnea syndrome. **p* < 0.05 for comparison between age groups ($\chi^2$ test)

about 30 kg in surgery-induced weight loss). Lower weight loss after surgery with aging might be explained, at least in part, by an age-dependent reduction in physical activity [38], or by larger energy intake after bariatric surgery, as described in older women with obesity [39].

In parallel with lower weight loss, a major finding was the lower LBM loss in OP compared to YP. This result may suggest safety of bariatric surgery in terms of risk of sarcopenia in aging subjects. However, assessment of muscle function would be required to confirm such an effect [40], as recommended for diagnosis of sarcopenia [40]. In a recent study, Alba et al. assessed in adults with a mean age of 45 years that relative muscle strength and physical function improved meaningfully after gastric bypass associated with loss of LBM [41]. In our recently published trial testing the effects of resistance training and additional protein intake after bariatric surgery in women with a mean age of 42.4 years, increased muscle strength was found without effect on LBM [16]. It is known that muscle strength does not depend solely on muscle mass, and the relationship between strength and mass is not linear [42]. These data emphasize the need for further studies with detailed and validated measures of muscle function before and after bariatric surgery in older patients.

Using a repeated measures design with DXA, we were able to document a differential pattern of change in FM and LBM. Whereas FM showed a continuous decrease over time after surgery in both age groups, LBM loss plateaued after 6 months in OP but not in YP. We observed the same effect in obese female patients (mean age 39.5 y) after LRYGBP [12, 20]. Moreover, despite a lower preoperative measured REE in OP, we found no difference in postoperative measured REE between our contrasted age groups, in parallel with a lower LBM loss.

In parallel with weight and body composition changes, we observed that the diabetes resolution rate was lower in OP, and the same was observed for resolution or improvement in hypertension, dyslipidemia, OSA, and knee pain. The lower rate of diabetes remission was expected by higher Diarem and Addiarem scores in the OP group [25, 43]. These results about comorbidity resolution are in agreement with one previous study where diabetes, hypertension, and OSA remission rates at 24 months were significantly different between elderly and younger subjects (59, 27, and 80% vs. 90, 79, and 85%, respectively) [7]. Our data however contrasts with findings from several other reports [5, 15, 34, 44]. Part of these discrepancies could be due to the original matching we performed on presurgical glycemic status or the very strict diabetes remission definition herein used (i.e., the latest ADA definition [24]). Overall, these data point to an improvement in the cardiometabolic disease profile which fits well with the lower loss in trunk fat associated with lower loss in total FM in aging subjects. Trunk FM includes abdominal fat and more specifically visceral fat which is recognized to strongly influence the development of cardiometabolic abnormalities [45].The lower rate of diabetes resolution could also be related to higher age, diabetes duration, and insulin requirements observed in aging subjects and which are known predictors of diabetes resolution [25].

We did not observe significant differences in mineral and micronutrient preoperative deficiencies between older and younger patients, even if we found one year after surgery a trend to higher risk of anemia and a trend to higher risk of malnutrition in OP, and, in contrast, significatively less vitamin D, iron and folates deficiencies in OP. Two studies showed no difference in nutritional parameters in older patients but with small sample size and without matching [34], or without comparison with younger patients [46]. In a case-control study, Bergeat et al. show that iron and vitamin B12 deficiencies were less prevalent in patients ≥ 60 years [44]. These findings underline the importance of adherence to a systematic postoperative prescription of micronutrient supplementation, whatever type of surgery [20].

Strengths of this study include the prospective data collection, the careful matching of OP with YP, the serial measurements during follow-up including DXA, and the use of an accurate definition for diabetes remission. This is also the only study with a sample size of over 50 older subjects to assess mineral and micronutrient deficiencies. Some limitations should be acknowledged including the retrospective study design, and the 12-month follow-up duration.

## Conclusion

In conclusion, bariatric surgery in patients over 60 years of age compared to younger counterparts was associated after 1 year of follow-up with lower loss in weight and fat mass but also in lean body mass, and lower remission rates of obesity-related comorbidities, without evidence of difference in nutritional status or rate of adverse events. The data suggest that bariatric surgery is a safe option for aging patients with obesity, but is not as effective for weight loss and related outcomes. Further prospective studies with longer-term follow-up are needed with detailed assessment of dietary intake, nutritional parameters, and muscle function to gain better insight into the risk of sarcopenia during the aging process after bariatric surgery.

**Acknowledgments** The authors express their thanks to Sophie Festis and to Dr. Florence Marchelli, MD, both at the Nutrition Department, Pitié-Salpêtrière Hospital, Paris, France, for technical assistance with DXA measurements and for assistance with data management, respectively.

### Compliance with Ethical Standards

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

**Ethical Statement** The study was approved by the local ethics committee.

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