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Original article

Evolution of body composition of obese patients undergoing bariatric surgery

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SUMMARY

Background & aims: Bariatric surgery is increasingly common in the fight against morbid obesity. However, after this intervention, it is not fully understood the evolution of weight loss and how body composition changes. The objective of this work is to study the evolution after surgery of weight and body composition of obese patients that underwent bariatric surgery.

Methods: In this retrospective and prospective study, we studied initially BMI and body composition of obese patients who attended nutritional appointments at Centro Hospitalar São João E.P.E. We collected personal data and anthropometric measurements between the pre-surgery appointment up to 60 months after surgery.

Results: The sample consisted of 793 patients, of which 86.5% were female and 13.5% were male, with a mean age of 43 years (SD = 10.5 years) and mean height of 1.62 m (SD = 0.079 m). Patients undergoing gastric band, sleeve gastrectomy and gastric bypass had, respectively, an initial BMI reduction of 6.3 kg/m^2, 13.2 kg/m^2 and 15.4 kg/m^2 and an initial fat mass% reduction of 4.4%, 14.3% and 17.3%. On the other hand, they had an initial increase of 3.2%, 10.8% and 12.4% of water%, 1.4%, 3.9% and 4.6% of fat and water-free mass%, and 1.9%, 7.3% and 8.9% of skeletal muscle mass%, respectively. BMI and fat mass% on average had a large decrease in the first 12 months, increasing slightly from 24 months onwards. The opposite behaviour was observed for water%, fat and water-free mass% and skeletal muscle mass%.

Conclusions: Bariatric surgery initially allows a substantial decrease in BMI as well as beneficial changes in the overall body composition of the individuals. Gastric bypass was the method that caused the most changes, followed by sleeve gastrectomy and, finally, gastric band. On average, after 24 months of follow-up, and for all surgical procedures studied, we observed a reversion in BMI and body composition values, showing the difficulties in maintaining weight and fat loss.

Introduction

Obesity, in recent decades has become a public health problem [1]. It is defined as a chronic disease with multifactorial genesis and is characterized by an accumulation of abnormal or excessive fat that may have a negative impact on the health of the individual [2]. It occurs mainly due to a high energy intake and low levels of physical activity being directly related to an increase in comorbidities and mortality[1,2]. Obese individuals have a higher risk of developing type 2 diabetes, cardiovascular, hepatic, musculoskeletal and respiratory diseases, some neoplasms, as well as psychological illnesses, resulting in a decline in the quality of life [2–6].

According to the World Health Organization [2], obesity is characterized by a BMI $\geq$ 30 kg/m^2 [7]. Even though this index is very useful for the population, it has been criticized for not reflecting the amount and distribution of body fat [2,7,8]. With the development of equipment to measure body composition, such as bioimpedance analysis, it became easier to classify individuals according to their fat mass [9]. Cut-off points to define obesity

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according to body fat mass percentage are 25% for men and 30% for women [10].

Intentional weight loss, by obese people, especially if maintained over a long period, can manifest in increased overall health and quality of life, in reduced mortality and improvements in associated chronic diseases, with emphasis on type 2 diabetes [1]. In cases of morbid obesity, lifestyle changes, like diet and exercise, often referred to as conservative therapies, rarely result in a significant and prolonged weight loss [11]. Thus, in order to improve the associated comorbidities, there was a search for more aggressive measures [11] such as bariatric surgery [12]. The most common procedures are Roux-en-Y gastric bypass (RYGB), gastric sleeve (GS) and laparoscopic adjustable gastric band (AGB) [13,14].

Even though there is research regarding bariatric surgery, there is scarce literature on long term maintenance of weight loss after surgery as well as changes in the body composition of patients. This work comes as an attempt to answer some questions that have been put in this area and has as objectives:

- To evaluate the evolution of BMI before and up to 60 months after surgery.
- Verify changes in body composition before and up to 36 months after surgery.

Materials and methods

In this cohort study, we retrospectively and prospectively evaluated obese patients at Centro Hospitalar São João E.P.E. (CHSJ), Porto, Portugal, that underwent bariatric surgery: AGB, GS or RYGB. These patients fulfilled the requirements according to normative circular 20/2008 of the Portuguese General Health Department to undergo bariatric surgery [15]. We excluded the individuals that were not evaluated at least 3 times between January 2010 and December 2016 with additional exclusion criteria: becoming pregnant in this period, having a pacemaker, prosthesis, or any other condition that might affect or be affected by the body composition assessment. This study was approved by the Ethics Committee for Health of the CHSJ.

When present, we collected weight data in the initial and follow-up appointments after surgery: 1st month, 3rd month, 6th month, 12th month, 18th month, 24th month, 30th month, 36th month, 48th month and 60th month. Body composition was available up to 36 months.

Measurements of weight (kg), fat mass (%), lean mass (kg), water mass (kg) and skeletal muscle mass (SMM, kg) were performed at the initial appointment and from the 6th to the 36th postoperative month by the InBody model 230, while at the 1st and 3rd month post-surgery, the InBody model 720 was used. After the 48th month, weight was measured using a SECA model 769 scale. Using the reported height, we computed the body mass index (BMI, kg/m^2). From the values of SMM and body water, we calculated the percentage of these in relation to the body weight (SMM% and water%, respectively). From the percentage of water and fat, we computed the percentage of fat and water free mass (FWFM = 100% - %fat - %water).

In the appointment prior to surgery, a hypoenergetic food plan or food counselling was prescribed, in order to cause weight loss until surgery. After surgery, a hypoenergetic food plan was given, 1200 kcal to women and 1500 kcal to men. Food consistency was adapted in the period after surgery: liquid in the 1st month and soft in the 2 nd month. In each evaluation the increase in physical activity was encouraged.

The results were analysed using IBM® SPSS™ Statistics for Windows, version 24. We considered a statistical significance of 5%.

Results

The sample consisted of 793 patients, of whom 686 (86.5%) were female and 107 (13.5%) were males, with a mean age of 43 years (SD = 10.5 years) and a mean height of 1.62 m (SD = 0.079 m). Regarding the type of surgery, 114 (14.4%) patients were submitted to AGB, 193 (24.3%) to GS and 486 (61.3%) underwent RYGB. The retrospective nature of our study implied that we were not able to obtain complete data for all patients, in particular for patients that were operated less than 5 years ago or due to patient withdrawal (Table 1).

We observed a decrease in mean BMI from 43.5 kg/m^2, at the date of surgery, to 33.3 kg/m^2, at the end of 60 months after surgery. However the magnitude of the differences depended on the type of surgery performed (Fig. 1).

In the case of AGB, the mean BMI decreased 6.3 kg/m^2 after surgery up to the 6th month ($p < 0.001$). Furthermore, these individuals had an increase in the mean BMI of 0.9 kg/m^2 between the 36th and 48th months ($p = 0.018$).

In the case of GS, between the pre-surgery evaluation and surgery there was an increase in the mean BMI of 0.4 kg/m^2 ($p = 0.032$). After surgery, there was a significant decrease up to 12 months of 13.2 kg/m^2 ($p < 0.001$). Moreover, between the 18th and 30th months and between the 36th and 48th months, there was an increase in the mean BMI of 0.9 ($p \leq 0.036$) and 1.0 kg/m^2 ($p = 0.035$), respectively.

Patients submitted to RYBG had a mean increase in BMI prior to surgery of 0.6 kg/m^2 ($p < 0.001$). After this, they had an average decrease until the 18th month after surgery ($p < 0.001$), totalling 15.4 kg/m^2. Additionally, between the 24th and 48th month after surgery, these individuals had an increase of 1.4 kg/m^2 ($p \leq 0.004$).

We observed that the mean BMI differed between surgery types, being lower for AGB up to the surgery ($p \leq 0.024$) and higher for AGB and lower for RYGB after surgery up to the 48th month ($p < 0.001$). The magnitude of the differences between the means ranged from an initial value of 1.50 kg/m^2, to 6.14 kg/m^2 at 12 months, being reduced from that moment on.

Of the patients submitted to GS and RYGB, some of them were previously submitted to AGB, 27 and 64, respectively. When we compare these patients that underwent revision surgery with those that did bariatric surgery for the first time (Figs. 2 and 3), we

Table 1
Number of patients with data available for each parameter at each evaluation period.

	Initial	Surgery	Time (months)									
			1st	3rd	6th	12th	18th	24th	30th	36th	48th	60th
BMI (kg/m^2)	759	787	735	711	663	561	430	364	274	246	146	75
Fat mass (%)	419	–	546	548	479	417	296	249	173	162	–	–
Water (%)	373	–	491	481	439	382	277	234	169	157	–	–
FWFM (%)	373	–	491	481	436	381	276	233	169	157	–	–
SMM (%)	373	–	493	484	439	381	277	234	170	157	–	–

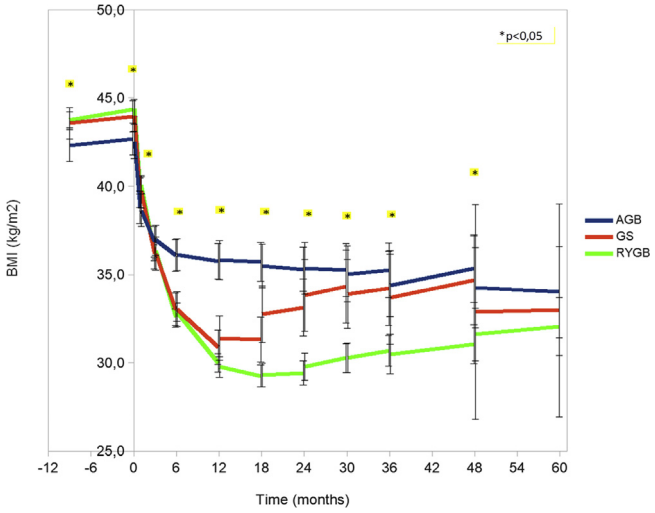

Fig. 1. Average BMI as a function of time and by surgery type: Roux-en-Y gastric bypass (RYGB), gastric sleeve (GS) and laparoscopic adjustable gastric band (AGB). The BMI increases up to the date of the surgery and decreases after it, with a partial recover after reaching its minimum. * ANOVA's test for the difference of mean BMI between surgery types.

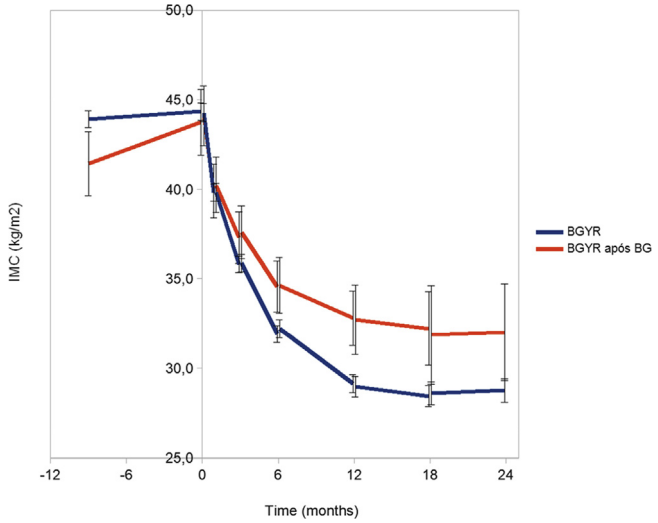

Fig. 3. Average BMI as a function of time and by previous surgery: Roux-en-Y gastric bypass (RYGB) as a first surgery or RYGB done after previous laparoscopic adjustable gastric band (AGB). Those with previous surgery had lower average decrease in BMI. * Student's t test for the difference of mean BMI between surgery types.

observe that the latter had a larger decrease in the mean BMI for both surgeries. At the 12th month after surgery, the mean difference for GS is 3.0 kg/m^2, $p = 0.014$; and for RYGB, the mean difference is 3.8 kg/m^2, $p < 0.001$.

We verified that the percentage of fat mass has a behaviour similar to the BMI, both along the time and when comparing surgery types. On the other hand, we observe the symmetric behaviour for the percentage of water, FWFM and SMM (Figs. 4–7).

Regarding fat mass, subjects who underwent AGB had a significant decrease of 4.4%, between the 1st and the 3rd month after surgery ($p < 0.001$). In GS and RYGB, between the pre-surgery evaluation and the 12th month after surgery there was a decrease in fat mass of 14.3% ($p \leq 0.007$) and 17.3% ($p \leq 0.002$), respectively. Between the 18th and 24th month, there was an increase of more 1.2% ($p = 0.030$) in the individuals who performed GS and 0.8% ($p = 0.022$) in those who performed RYGB.

The percentage of body water increased 3.2% on average between the 1st and the 3rd month after surgery for patients submitted to AGB ($p < 0.001$). For patients that underwent GS or RYGB, the body water increased 10.4% and 11.5%, respectively, from the 1st to the 12th month after surgery ($p < 0.001$).

The skeletal muscle mass (SMM) in patients that underwent AGB, had an increase of 1.9% ($p < 0.001$) between the 1st and 3rd month after surgery. In patients submitted to GS and RYGB, between the 1st and 12th month after surgery the SMM increased 7.3% ($p < 0.001$) and 8.9% ($p < 0.001$), respectively.

The mean of the percentage of fat and water free mass (FWFM) increased 1.2% between the 1st and the 3rd month after surgery in

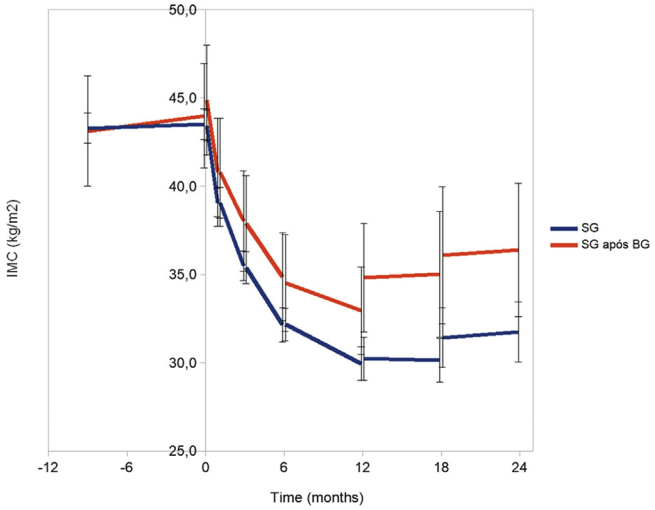

Fig. 2. Average BMI as a function of time and by previous surgery: gastric sleeve (GS) as a first surgery or GS done after previous laparoscopic adjustable gastric band (AGB). Those with previous surgery had lower average decrease in BMI. * Student's t test for the difference of mean BMI between surgery types.

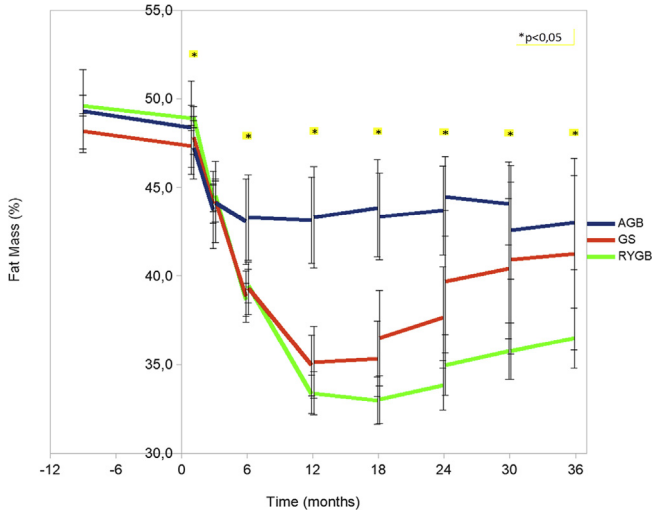

Fig. 4. Average fat mass percentage as a function of time and by surgery type: Roux-en-Y gastric bypass (RYGB), gastric sleeve (GS) and laparoscopic adjustable gastric band (AGB). * ANOVA's test for the difference of mean fat mass percentage between surgery types.

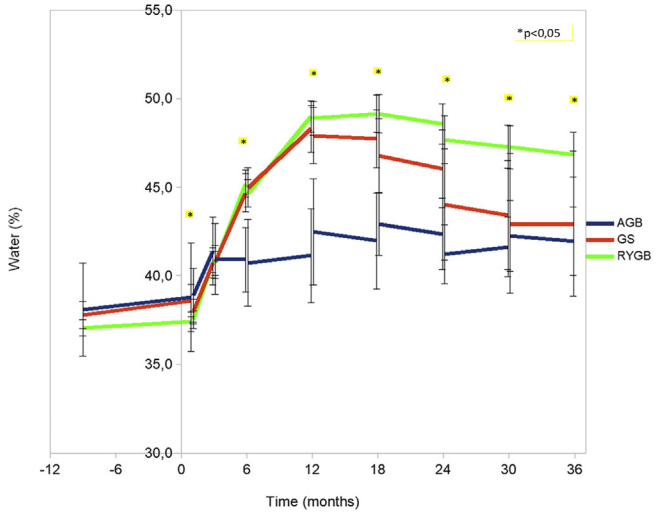

Fig. 5. Average body water percentage as a function of time and by surgery type: Roux-en-Y gastric bypass (RYGB), gastric sleeve (GS) and laparoscopic adjustable gastric band (AGB). * ANOVA's test for the difference of mean body water percentage between surgery types.

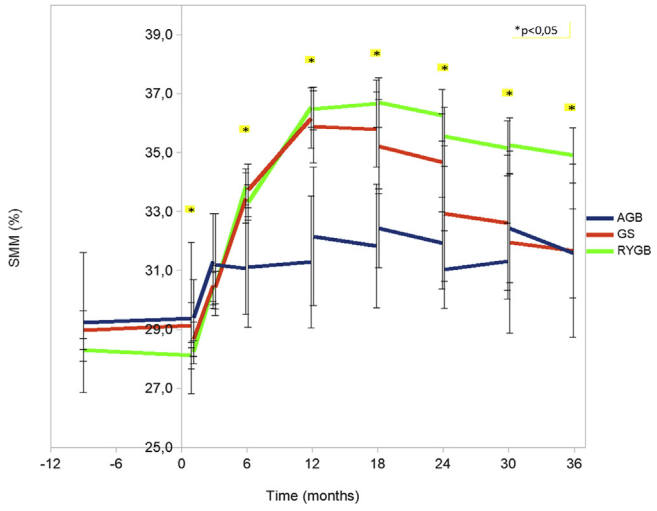

Fig. 6. Average skeletal muscle mass (SMM) percentage as a function of time and by surgery type: Roux-en-Y gastric bypass (RYGB), gastric sleeve (GS) and laparoscopic adjustable gastric band (AGB). * ANOVA's test for the difference of mean skeletal muscle mass between surgery types.

patients subjected to AGB ($p < 0.001$). In those submitted to GS and RYGB, between the 1st and the 12th month post surgery, there was an increase of 3.9% ($p < 0.001$) and 4.3% ($p < 0.001$), respectively.

Discussion

The weight loss we observed was not enough for most patients to stop being obese. Furthermore, the mean variation of BMI depended on the surgery type: we found a larger average decrease for RYGB and smaller decrease for AGB.

The increase in BMI prior to surgery that we observed is corroborated by a study realized by Benotti et al. [16]. From our clinical experience, we know that a fair number individuals use this period to ingest large portions of food with high energetic value, usually rich in fat and sugar, that they know that will not be "allowed" or advised after the surgical intervention.

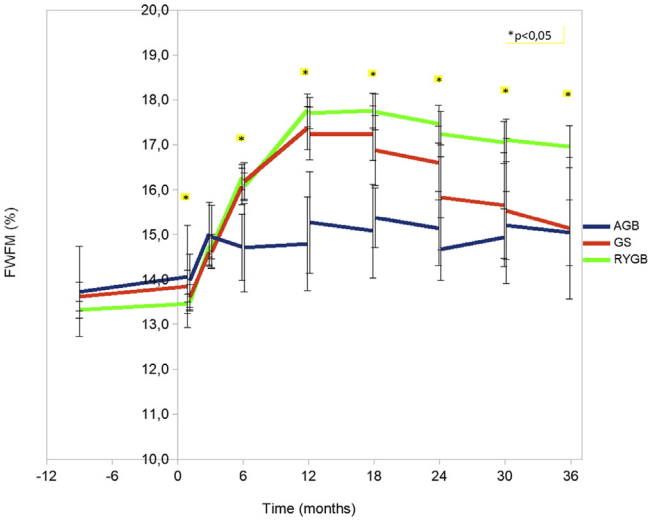

Fig. 7. Average fat and water free mass (FWFM) percentage as a function of time and by surgery type: Roux-en-Y gastric bypass (RYGB), gastric sleeve (GS) and laparoscopic adjustable gastric band (AGB).* ANOVA's test for the difference of mean fat and water free mass between surgery types.

Furthermore, our results are also in line with the study carried out by Carvalho et al. [12], which evaluated 191 female patients, submitted to AGB ($n = 64$) and GS ($n = 56$). They were evaluated before and during one year after the surgical intervention, reporting a BMI decrease from 43.8 kg/m^2 to 33.3 kg/m^2. Women submitted to AGB had a significant mean increase in BMI in the period preceding surgery. After surgery, they recorded a weight loss of 41.6% until the 6th month. After that period, they had an increase in mean BMI until the 12th month. On the other hand, women who underwent GS had weight loss up to the 12th month, making a total excess weight loss of 72.6% when compared to the time before surgery. Despite this initial weight loss, as in the present study, both surgeries showed a significant increase in mean BMI at a time after 12 months. These results also are in agreement with a study conducted by Inácio et al. [17] where 141 female patients submitted to AGB ($n = 76$) and RYGB ($n = 65$) were evaluated before and during 1 year after the surgical intervention, with a BMI decrease from 43.8 kg/m^2 to 33.2 kg/m^2, which was more pronounced in the first 6 months.

A study by Sjöström et al. [18] evaluated 156 patients who underwent AGB and 34 patients who underwent RYGB for 10 years. During this time, weight loss was maximal after 12 months. After this date, mean BMI had a tendency to increase, being weight loss, at the end of the study, less 25% (RYGB) and 13.2% (AGB) when compared to that period.

In regard to BMI in revision surgery, a study by Chowbey et al. [19]. Concluded that even though there is a decrease in the sample that is submitted to revision surgery, the decrease in BMI is greater in those that are submitted for the first time to RYGB (12 months after surgery: RYGB: less 15.2 kg/m^2 vs. AGB + RYGB: less 9.8 kg/m^2).

A limitation of this study was that height was reported instead of measured. However, a research study by Pinhão et al. [20] in 3529 individuals concluded that reported stature has a very strong correlation and small differences when compared to the actual one. Hence, we estimate that the differences in our results would be small.

Regarding body composition evolution of this study's patients, we observed that there was a decrease in fat mass percentage and an increase in the percentage of water, FWFM and SMM, regardless

of the type of surgery performed. AGB showed significant changes up to 3 moths, while GS and RYGB presented differences up to 12 months after surgery. These data are supported by a study conducted by Strain et al. [21], where they showed that the patients submitted to RYGB had a greater decrease in the mean values of body fat mass than the other two types of surgery (RYGB: 16.1%; GS: 11.5%; AGB, 6.0%).

A research study conducted by Wells et al. [22] also showed that, after 12 months, in regard to fat mass and fat free mass, RYGB showed greater differences than GS (fat mass; RYGB: - 16,95% vs GS: - 10,83%; fat free mass: RYGB: + 17,06% vs GS: + 10,77%).

Since we observed that, in the first few months after surgery, there was a decrease of fat mass, water mass and FWFM, the increase in the percentage of body water is likely to be due mainly to the higher rate of decrease of fat mass after surgery.

We would like to emphasize the large sample size (n = 793), as well as the longitudinal nature of this research work (60 months), as strengths of this study.

This investigation allowed us to conclude that bariatric surgery initially allows a substantial decrease in BMI as well as beneficial changes in the overall body composition of the individuals.

Of the three methods, RYGB was the method associated with the largest variations of BMI and body composition, followed by GS and, finally, AGB. We also concluded that those who underwent bariatric surgery only once achieved a lower BMI in comparison to those who underwent a revision surgery.

We also verified that in the last months of follow-up, regardless of the surgery, there was a regression of the different indicators showing that these improvements are, on average, transient. After 36 months, on average, many patients had regain weight, at the expense of an increase in the percentage of body fat, rather than lean body mass.

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Statement of authorship

Luís Bernardo Silva collected the data and wrote the first draft of the manuscript; Bruno M.P.M. Oliveira and Flora Correia helped to draft the manuscript and reviewed the final version. Bruno M.P.M.P. did the statistical analysis. All authors read and approved the final manuscript.

Conflict of interest statement

None declared.

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