OBES SURG (2014) 24:232–240
DOI 10.1007/s11695-013-1061-5

ORIGINAL CONTRIBUTIONS

Six-Month Intragastric Balloon Treatment for Obesity Improves Lung Function, Body Composition, and Metabolic Syndrome

Thiago Thomaz Mafort · Eduardo Madeira · Miguel Madeira · Erika Paniago Guedes · Rodrigo Oliveira Moreira · Laura Maria Carvalho de Mendonça · Maria Lucia Fleiuss Farias · Agnaldo José Lopes

Published online: 16 August 2013

Abstract
Background The purpose of this study is to establish whether the use of an intragastric balloon (IGB) for 6 months improves lung function, metabolic parameters, and body fat distribution in patients with overweight/obesity and metabolic syndrome (MS).
Methods This is a longitudinal and interventional study on 40 adults, whose anthropometric, laboratory, and lung function parameters were assessed and who underwent dual-energy X-ray absorptiometry (DXA) before implantation and after removal of IGB.
Results The total lung capacity (TLC) (p=0.0001), functional residual capacity (FRC) (p=0.0001), residual volume (p=0.0005), and expiratory reserve volume (ERV) (p=0.0001) were significantly reduced by IGB. The body mass index (BMI) significantly decreased from a median of 39.1 kg/m^2 at the beginning of the study to 34.5 kg/m^2 at the end of the 6-month period (p=0.0001). At the end of the study, 31 participants (77.5 %) no longer met the diagnostic criteria of MS. The percentage of truncal, android, gynoid, and total fat investigated by DXA exhibited significant reductions (p=0.0001). Significant correlations were found between delta TLC and delta waist circumference (ρ=−0.34; p=0.03), delta FRC and delta IMC (ρ=−0.39; p=0.01), delta ERV and delta BMI (ρ=−0.44; p=0.005), and delta ERV and delta high-density lipoprotein (HDL) (ρ=−0.37; p=0.02). Significant correlations were also found between delta ERV and delta truncal (ρ=−0.51; p=0.004), android (ρ=−0.46; p=0.01), gynoid (ρ=−0.55; p=0.001), and total fat (ρ=−0.59; p=0.0005).
Conclusions IGB efficiently induced weight loss and promoted the improvement of lung function parameters, with a reduction of the restrictive ventilatory defect. It also promoted improvements of MS and the pattern of body fat distribution.

T. T. Mafort
Postgraduate Programme in Medical Sciences, State University of Rio de Janeiro, Boulevard 28 de Setembro, 77, Vila Isabel, Rio de Janeiro, Brazil
e-mail: tmafort@gmail.com

E. Madeira · M. Madeira · M. L. F. Farias
Postgraduate Programme in Endocrinology, Federal University of Rio de Janeiro, Rua Rodolpho Paulo Rocco, 255, Cidade Universitária, Ilha do Fundão, Rio de Janeiro, Brazil

E. Madeira
e-mail: dudamadeira@gmail.com

M. Madeira
e-mail: migmadeira@gmail.com

M. L. F. Farias
e-mail: fleiuss@hucff.ufrj.br

E. P. Guedes · R. O. Moreira
Endocrinology Department, State Institute of Diabetes and Endocrinology, Rua Moncorvo Filho, 90, Centro, Rio de Janeiro, Brazil

E. P. Guedes
e-mail: erikapaniago@uol.com.br

R. O. Moreira
e-mail: rom_br@yahoo.com

L. M. C. de Mendonça
Rheumatology Department, Federal University of Rio de Janeiro, Rua Rodolpho Paulo Rocco, 255, Cidade Universitária, Ilha do Fundão, Rio de Janeiro, Brazil
e-mail: laura.mendonca@uol.com.br

A. J. Lopes (✉)
Postgraduate Programme in Medical Sciences, State University of Rio de Janeiro, Rua Araguaia, 1266, bloco 1/405, Freguesia, Jacarepaguá, Rio de Janeiro, RJ, Brazil
e-mail: phel.lop@uol.com.br

Keywords Obesity · Weight loss · Gastric balloon · Respiratory function tests

Introduction

Several areas of the world, Latin America in particular, have undergone deep a socioeconomic and demographic transformation accompanied by changes in the lifestyle, dietary habits, and patterns of disease prevalence. As a consequence, the numbers of obese individuals and patients with metabolic syndrome (MS) have exhibited remarkable increases in Latin America [1]. Recent data from the Brazilian Health Ministry show that obesity and overweight rate are increasing in prevalence. According to the World Health Organization (WHO) criteria, the proportion of individuals with overweight in Brazil (BMI between 25 and 29.9 kg/m^2) increased from 42.7 % in 2006 to 48.5 % in 2011, while the percentage of obese people (BMI ≥30 kg/m^2) increased from 11.4 to 15.8 % in the same period [2, 3]. The treatment of obesity is usually complex and requires a multidisciplinary approach, ranging from behavioural changes to bariatric surgery. The intragastric balloon (IGB) is one such option, considered a low risk procedure and with satisfactory results in the short term [4]. A recent meta-analysis reported average weight loss of 12.2 % and body mass index (BMI) reduction of 5.7 kg/m^2 when IGB was used over a 6-month period [4].

Obesity causes alterations of lung function. Several factors interfere with the respiratory mechanics in obese individuals. Excess adipose tissue induces mechanical compression on the diaphragm, lungs, and chest, which might lead to restrictive respiratory failure [5]. As a function of the inefficacy of the respiratory muscles, their strength and endurance might be reduced in obese [6]. Interestingly, because MS also alters lung function, the lungs might be exposed to greater damage in MS combined with obesity than in either condition alone [7].

Dual-energy X-ray absorptiometry (DXA) has been increasingly used to assess obesity [8]. DXA has revealed a correlation between the lung function and body fat distribution of obese patients [9]. Studies that used DXA suggest that fat deposition in the trunk and a predominance of the gynoid pattern of distribution bear a close correlation with the decline of lung function [10]. Other studies showed that, in men, the lean mass exerts a positive influence on lung function, whereas the influence of central fat deposition is negative [11].

Studies that assessed weight loss induced by either bariatric surgery or low-calorie diets showed that lung function improves as BMI decreases [12]. However, there are no data on the use of IGB and the effects of the associated weight loss on lung function, the pattern of body fat deposition, and the parameters of MS. Therefore, the primary aim of our study was to perform a longitudinal analysis of the effects of IGB on lung function, DXA parameters, and MS indicators. In addition, we assessed the correlation between changes in lung function and the effects of weight loss on the MS and DXA parameters after 6 months of use of IGB.

Patients

This was a longitudinal and interventional study conducted from June 2011 to September 2012 with 52 patients aged 18 to 65 years. All the participants exhibited overweight or obesity according to the WHO criteria [2] in addition to MS according to the criteria of the International Diabetes Federation [13]. The exclusion criteria were type 1 or 2 diabetes mellitus, pregnancy, previous stomach surgery, hiatal hernia ≥5 cm, clotting disorders, potentially bleeding gastrointestinal lesions, and alcoholism or use of drugs. The study was approved by the institutional research ethics committee. All patients signed an informed consent form. The study is registered at ClinicalTrials.gov (identifier, NCT01598233).

Methods

MS was defined by the presence of central obesity (waist circumference (WC) >80 cm in women and >90 cm in men), arterial hypertension (arterial pressure ≥130/85 mmHg), increased blood glucose (fasting glycaemia ≥100 mg/dL or diagnosis of diabetes mellitus), hypertriglyceridaemia (triglycerides ≥150 mg/dL or treatment for dyslipidaemia), and reduced high-density lipoprotein (HDL) (<40 mg/dL in men or <50 mg/dL in women) [13].

A silicone IGB (Silimed Silicone Instrumental Médico-cirúrgico Hospitalar Ltda, Rio de Janeiro, RJ, Brazil) was implanted by upper gastrointestinal endoscopy under deep sedation. Under endoscopic visualisation, the IGB was placed in the stomach and filled with 650 mL of normal saline solution (0.9 % NaCl) and 20 mL of methylene blue solution. According to local regulations and our institutional ethics committee, all patients remained in the hospital up to 24 h following the procedure [14].

The lung function parameters were assessed before IGB implantation and after IGB removal by spirometry, static pulmonary volumes using the helium dilution, carbon monoxide lung diffusion capacity (DLco), muscle inspiratory strength (MIP), and muscle expiratory strength (MEP). The tests were performed using Collins Plus Pulmonary Function Testing Systems (Warren E. Collins, Inc., Braintree, MA, USA). Brazilian reference values were used [15–18].

The pattern of body fat distribution was assessed by DXA using a Prodigy-GE densitometer (GE Healthcare, Inc., Madison, WI, USA). The tests were performed before implantation and immediately after the removal of the IGB. The

truncal pattern of fat distribution was characterised by preferential fat deposition in the trunk, the android pattern by fat deposition in the abdomen, and the gynoid type by fat deposition in the gluteal–femoral area [19].

Statistical Analysis

The data are expressed as median and interquartile range or as frequencies. Non-parametric methods were used because most of the variables related to lung function did not exhibit a normal distribution according to the Shapiro–Wilk test. The changes in pulmonary function, MS, and DXA after 6 months of IBG use were assessed by the Wilcoxon signed-rank test or McNemar's test. The participants were divided in two subgroups based on the presence or absence of MS after the removal of IGB, and the absolute changes in the lung function variables between these two subgroups were assessed by the Mann–Whitney test. The correlations were analysed by Spearman's correlation coefficient. The level of significance was established as 5 %. Statistical analysis was performed using SAS v.6.11 (SAS Institute, Inc., Cary, NC, USA).

Results

The initial sample comprised 52 patients, six of whom were excluded because they exhibited complications that required early IGB removal: five because of gastric intolerance and one due to rupture of the device. All these complications occurred within the first 8 weeks of IGB use. Another six patients did not perform the lung function tests on schedule and were also excluded. Therefore, 40 patients completed the study. DXA before and after treatment was performed in 31 participants because the tests could not be performed in six patients due

Table 1 Values of pulmonary function at baseline

Variables	Baseline
FVC (% predicted)	89 (78–99.5)
FEV_1 (% predicted)	88 (78–96)
FEV_1/FVC (%)	85.0 (82.5–88.8)
MIP (% predicted)	78.5 (59–106.8)
MEP (% predicted)	50 (40.3–60.5)
TLC (% predicted)	83 (75–88)
FRC (% predicted)	74 (63.3–82.8)
RV (% predicted)	72 (59.5–78)
RV/TLC (%)	25.5 (22.0–29.8)
ERV (% predicted)	59.5 (33.3–101)
DLco (% predicted)	98.5 (86–108.8)

Results are medians (interquartile range) or number (%)

FVC forced vital capacity, *FEV_1* forced expiratory volume in 1 s, *MIP* maximal inspiratory pressure, *MEP* maximal expiratory pressure, *TLC* total lung capacity, *FRC* functional residual capacity, *RV* residual volume, *ERV* expiratory reserve volume, *DLco* carbon monoxide lung diffusion capacity

Table 2 Effects of intragastric balloon on weight, body mass index, and lung function parameters over a 6-month period

	Baseline	After 6 months	*p* value[a]
Weight (kg)	111 (95.5–119.8)	93.8 (80.2–108.7)	0.0001
BMI (kg/m^2)	39.1 (35.7–44.2)	34.5 (30.2–40)	0.0001
FVC (L)	3.21 (2.86–3.83)	3.38 (3.06–4.02)	0.0001
FEV_1 (L)	2.75 (2.35–3.14)	2.88 (2.57–3.26)	0.0001
FEV_1/FVC (%)	85 (82.5–88.8)	81 (79–84)	0.0001
MIP (cm H_2O)	68 (51.3–114.5)	68.5 (38.8–116.0)	0.21
MEP (cm H_2O)	85.5 (70.5–102.8)	74.5 (65–121)	0.91
TLC (L)	4.42 (3.83–4.87)	4.68 (4.17–5.60)	0.0001
FRC (L)	1.56 (1.36–1.83)	2.08 (1.69–2.42)	0.0001
RV (L)	1.13 (0.95–1.34)	1.30 (1.07–1.57)	0.0005
RV/TLC (%)	25.5 (22–29.8)	27 (24–32)	0.015
ERV (L)	0.39 (0.25–0.67)	0.74 (0.51–1.03)	0.0001
DLco (ml/min/mmHg)	22.8 (19.7–25.5)	22.7 (19.5–26.2)	0.36

BMI body mass index, *FVC* forced vital capacity, *FEV_1* forced expiratory volume in one second, *MIP* maximal inspiratory pressure, *MEP* maximal expiratory pressure, *TLC* total lung capacity, *FRC* functional residual capacity, *RV* residual volume, *ERV* expiratory reserve volume, *DLco* carbon monoxide lung diffusion capacity

[a] Wilcoxon signed-rank test

Table 3 Effects of intragastric balloon on metabolic syndrome and dual energy X-ray absorptiometry parameters over a 6-month period

Variables	*N*	Baseline	After 6 months	*p* value[a]
WC (cm)	40	113 (107.3–121)	105 (97–115)	0.0001
Glycemia (mg/dL)	38	98.5 (89.8–107.3)	90 (84.0–95.3)	0.0007
Triglycerides (mg/dL)	31	141 (120–235)	101 (66–130)	0.0001
HDL (mg/dL)	37	47 (39.5–53)	49 (44.5–56)	0.001
SBP (mmHg)	40	137 (123.5–144.8)	126.0 (120–137.8)	0.03
DBP (mmHg)	40	78.5 (71.0–86.8)	74.5 (69–80)	0.04
MS (%)	40	40 (100 %)	9 (22.5 %)	<0.0001[b]
BF-Trunk (%)	31	50.3 (46.7–52.6)	47 (41.8–50.8)	0.0001
BF-Android (%)	31	54.8 (51.9–58.1)	50.8 (46.1–56)	0.0001
BF-Gynoid (%)	31	52.6 (47.1–57.2)	49.7(42.0–54.4)	0.0001
BF-Total (%)	31	48.7 (41.8–51.8)	44.6 (37.7–49.3)	0.001

WC waist circumference, *HDL* high-density lipoprotein, *SBP* systolic blood pressure, *DBP* dyastolic blood pressure, *BF-Trunk* body fat percentage assessed in the trunk, *BF*-Android body fat percentage assessed in the android region, *BF-Gynoid* body fat percentage assessed in the gynoid region

[a] Wilcoxon signed-rank test

[b] McNemar's test

to technical reasons (excess weight) and three participants missed the appointments.

At the initial assessment of BMI, two participants (5 %) were overweight, five (12.5 %) had grade 1 obesity, 16 (40 %) had grade 2 obesity, and 17 (42.5 %) had grade 3 obesity. Twelve (30 %) participants exhibited restrictive ventilatory disorder, and in one (2.5 %) the FEV_1/FVC ratio was lower than 0.70. The initial values of lung function parameters are listed in Table 1.

After 6 months of IGB use, only five (12.5 %) participants exhibited restrictive ventilatory disorder, none a FEV_1/FVC ratio lower than 0.70, the MIP was reduced in 22 (55 %), and the MEP in 35 (87.5 %). DLco was reduced in three participants (7.5 %) and elevated in three others. Table 2 lists the effects of the use of IGB on weight, body mass index, and lung function parameters during the study. The weight lost at IGB removal was 11.8 % (7.3–20.2 %) of the initial weight.

Table 4 Spearman's correlation coefficients between the changes in the variables of lung function and metabolic syndrome

Variables		BMI	WC	Glycemia	TG	HDL	SBP	DBP
FVC	ρ	−0.16	−0.25	0.03	−0.05	0.04	0.11	0.15
	p	0.32	0.12	0.84	0.77	0.80	0.50	0.36
	N	40	40	38	31	37	40	40
FEV_1	ρ	−0.11	−0.21	0.06	−0.10	0.16	0.10	0.10
	p	0.51	0.20	0.74	0.59	0.35	0.52	0.55
	N	40	40	38	31	37	40	40
FEV_1/FVC	ρ	−0.06	−0.14	−0.03	−0.03	−0.01	−0.15	0.05
	p	0.71	0.38	0.86	0.86	0.94	0.35	0.77
	N	40	40	38	31	37	40	40
MIP	ρ	0.16	0.21	0.08	0.13	−0.17	−0.17	−0.02
	p	0.32	0.19	0.64	0.47	0.30	0.30	0.89
	N	40	40	38	31	37	40	40
MEP	ρ	0.19	0.27	0.07	0.34	−0.08	−0.05	−0.22
	p	0.24	0.09	0.67	0.06	0.64	0.76	0.17
	N	40	40	38	31	37	40	40
TLC	ρ	−0.29	−0.34	−0.10	−0.01	−0.16	−0.18	0.15
	p	0.07	0.03	0.56	0.97	0.35	0.26	0.36
	N	40	40	38	31	37	40	40
FRC	ρ	−0.39	−0.25	−0.15	0.04	−0.13	−0.29	−0.08
	p	0.01	0.12	0.38	0.83	0.44	0.07	0.63
	N	40	40	38	31	37	40	40
RV	ρ	−0.18	−0.16	−0.32	−0.04	−0.01	−0.23	0.09
	p	0.26	0.32	0.05	0.81	0.96	0.16	0.56
	N	40	40	38	31	37	40	40
RV/TLC	ρ	−0.15	−0.20	−0.16	−0.16	0.02	−0.23	0.10
	p	0.37	0.23	0.34	0.39	0.91	0.16	0.55
	N	40	40	38	31	37	40	40
ERV	ρ	−0.44	−0.26	0.10	0.31	−0.37	−0.27	−0.03
	p	0.005	0.11	0.56	0.09	0.02	0.09	0.83
	N	40	40	38	31	37	40	40
DLco	ρ	−0.11	−0.03	0.08	0.04	−0.14	−0.11	0.12
	p	0.50	0.87	0.64	0.82	0.42	0.49	0.47
	N	40	40	38	31	37	40	40

ρ Spearman's correlation coefficient, *N* number of cases considered, *BMI* body mass index, *WC* waist circumference, *TG* triglycerides, *HDL* high-density lipoprotein, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *FVC* forced vital capacity, *FEV_1* forced expiratory volume in one second, *MIP* maximal inspiratory pressure, *MEP* maximal expiratory pressure, *TLC* total lung capacity, *FRC* functional residual capacity, *RV* residual volume, *ERV* expiratory reserve volume, *DLco* carbon monoxide lung diffusion capacity

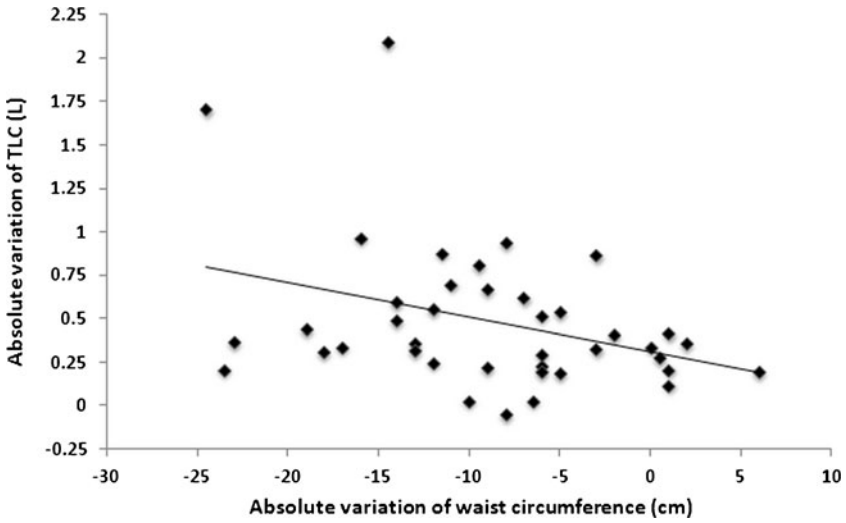

Fig. 1 Relationship of absolute variation of total lung capacity (*TLC*) with absolute variation of waist circumference over a 6-month period (ρ=−0.34; p= 0.03); correlation was determined using Spearman's rank correlation

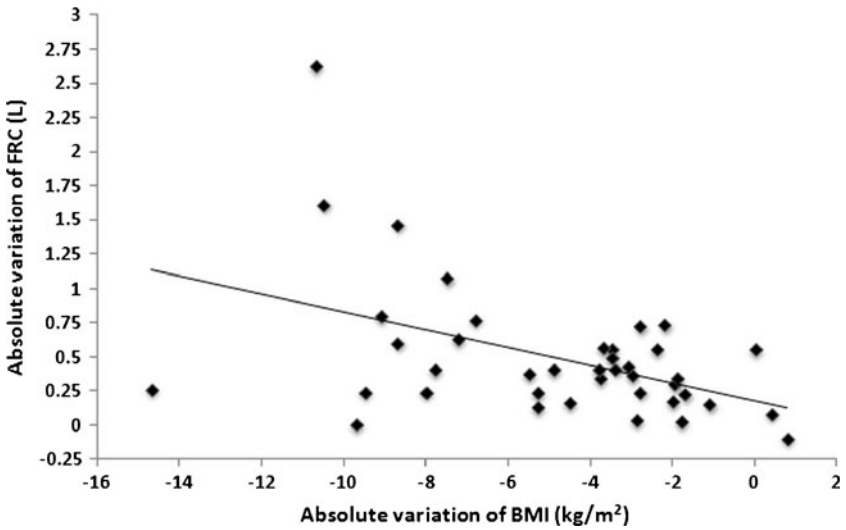

Fig. 2 Relationship of absolute variation of functional residual capacity (*FRC*) with absolute variation of body mass index (*BMI*) over a 6-month period (ρ=−0.39; p= 0.01); correlation was determined using Spearman's rank correlation

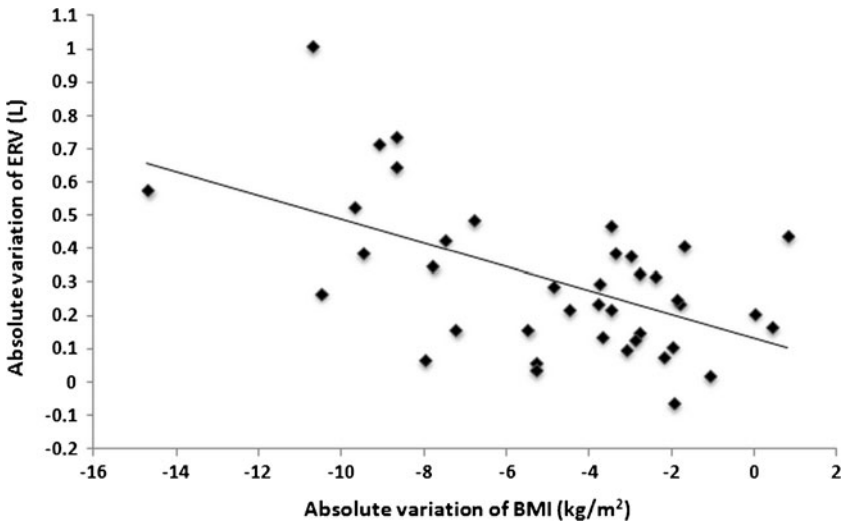

Fig. 3 Relationship of absolute variation of expiratory reserve volume (*ERV*) with absolute variation of body mass index (*BMI*) over a 6-month period (ρ=−0.44; p= 0.005); correlation was determined using Spearman's rank correlation

At the end of the study, only nine participants (22.5 %) met the diagnostic criteria of MS. Additionally, the parameters of body fat distribution assessed by DXA exhibited remarkable changes. These data are shown in Table 3.

Table 4 and Figs. 1, 2, and 3 show the correlations between the changes in lung function parameters and the changes in MS variables during the study. Table 5 and Figs. 4 and 5 list the correlations between the changes in lung function variables and the changes in DXA variables in the same 6-month period. A comparison of the participants with MS improvement to the ones without improvement did not find significant differences in the changes in lung function variables between these groups ($p<0.05$).

Discussion

The main finding of the present study was a significant BMI reduction following 6 months of IGB use. In addition, there was a statistically significant improvement for both the MS parameters and pulmonary function variables. A significant fat percentage reduction was observed in all assessed body areas. To the best of our knowledge, this is the first study that has found a positive effect with the use of IGB on the parameters of lung function and body fat distribution as measured by DXA.

In the present study a significant reduction in BMI was found after using the IGB for 6 months ($p=0.0001$). Because the risk of rupture of the device significantly increases after 6 months, this should be removed after this period [20]. Interestingly, it is believed that because an IGB occupies a large part of the stomach, it induces gastric fullness and early satiety, which favour the acceptability of the calorie-restricted diet prescribed during treatment, resulting in weight loss [21–23]. In addition, ghrelin production seems to be inhibited during the use of IGB, which contributes to satiety and thus to weight loss [24].

In addition to weight loss, we found significant body fat reduction in all the areas assessed by DXA after 6 months of IGB use. DXA is currently considered the gold standard for direct assessment of regional and total body fat and lean mass [8]. It is a non-invasive technique and provides reliable results with satisfactory accuracy [25]. Analysis of the regional fat distribution has paramount importance from the clinical point of view, as there are various phenotypes of obesity [26]. Interestingly, abdominal fat deposition is directly correlated with insulin resistance and other metabolic disorders, such as diabetes [27]. IGBs are also effective in the improvement of MS parameters [28, 29]. Crea et al. [30] reported improvement of MS parameters after 1 year of IGB use. Our study corroborates their results, as all the MS parameters improved. These results are worth emphasising because MS increases the risk of morbidity, cardiovascular disease in particular [31]. Several hypotheses have been formulated to account for the development of MS and its complications. The hypothesis that is currently most widely accepted suggests that a dysfunction of the adipose tissue alters the metabolism of free fatty acids and the release of adipokines, resulting in an inflammatory state and insulin resistance [32, 33].

Obesity alters the respiratory mechanics, thereby increasing the oxygen consumption. Lazarus et al. [34] showed that

Table 5 Spearman's correlation coefficients between the changes in the variables of lung function and dual energy X-ray absorptiometry

Variables		Trunk	Android	Gynoid	Total
FVC	ρ	0.01	0.02	0.01	−0.02
	p	0.98	0.90	0.95	0.93
	N	31	31	31	31
FEV_1	ρ	0.02	0.13	0.02	0.03
	p	0.90	0.48	0.90	0.89
	N	31	31	31	31
FEV_1/FVC	ρ	−0.08	−0.10	−0.19	−0.13
	p	0.68	0.59	0.31	0.48
	N	31	31	31	31
MIP	ρ	−0.22	0.03	−0.01	0.03
	p	0.24	0.86	0.96	0.85
	N	31	31	31	31
MEP	ρ	−0.09	0.03	0.04	0.06
	p	0.62	0.86	0.82	0.74
	N	31	31	31	31
TLC	ρ	−0.03	−0.33	−0.23	−0.22
	p	0.86	0.070	0.21	0.23
	N	31	31	31	31
FRC	ρ	−0.04	−0.15	−0.27	−0.20
	p	0.82	0.41	0.14	0.27
	N	31	31	31	31
RV	ρ	0.02	−0.14	−0.22	−0.15
	p	0.91	0.44	0.23	0.41
	N	31	31	31	31
RV/TLC	ρ	0.02	−0.14	−0.16	−0.14
	p	0.92	0.45	0.40	0.44
	N	31	31	31	31
ERV	ρ	−0.51	−0.46	−0.55	−0.59
	p	0.004	0.01	0.001	0.0005
	N	31	31	31	31
DLco	ρ	−0.28	−0.24	−0.17	−0.17
	p	0.13	0.19	0.36	0.37
	N	31	31	31	31

ρ Spearman's correlation coefficient, N number of cases consideredy, *FVC* forced vital capacity, FEV_1 forced expiratory volume in one second, *MIP* maximal inspiratory pressure, *MEP* maximal expiratory pressure, *TLC* total lung capacity, *FRC* functional residual capacity, *RV* residual volume, *ERV* expiratory reserve volume, *DLco* carbon monoxide lung diffusion capacity

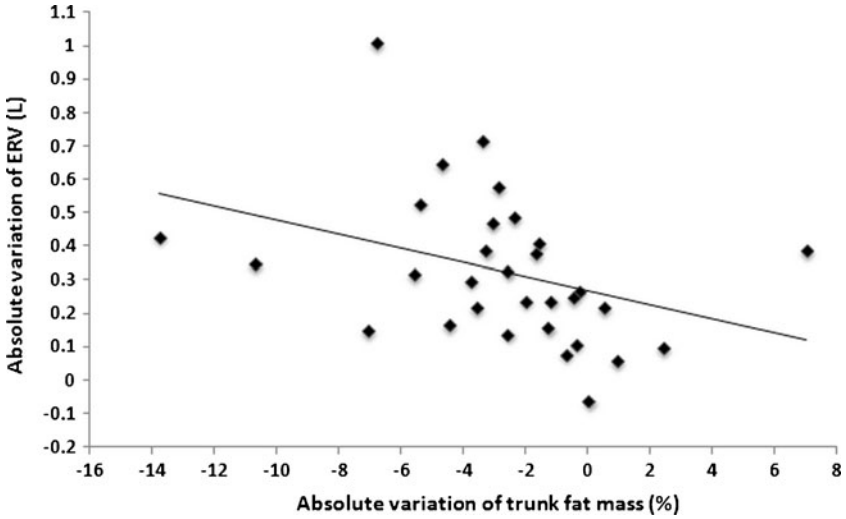

Fig. 4 Relationship of absolute variation of expiratory reserve volume (*ERV*) with absolute variation of trunk fat mass over a 6-month period (ρ=−0.51; p= 0.004); correlation was determined using Spearman's rank correlation

central fat deposition exerts a considerable impact on diaphragm mobility and modifies the lung volumes. In this regard, in obese individuals, the amount of abdominal fat was negatively correlated with chest wall compliance [35–37]. Additionally, Dixon et al. [38] emphasised the effects of obesity on lung function, observing that the impairment of the respiratory system function is not only due to the mechanical effects of fat deposition. In fact, the mediators produced by adipose tissue, i.e. the adipokines, also play important roles in lung tissue physiology. Medoff [39] and Konter et al. [40] investigated the effects of adipokines on the alveolar-capillary membrane and lung blood vessels and showed that they induce a pro-inflammatory state in the lung that contributes to lung damage in obesity. In the present study, FRC increased considerably after the use of IGB, and TLC, ERV, and ERV significantly increased. These results show that obesity has a tendency to induce restrictive disorder, which improves with the use of IGB [9].

The present study found a significant correlation between TLC and WC. These results further support the role attributed to abdominal fat in the development of restrictive disorder and its deleterious influence on ventilatory mechanics [41]. WC is related to the intra-abdominal and subcutaneous adipose tissue, and it seems to be a better indicator of intra-abdominal fat than BMI [42]. Therefore, elevated WC might be a predictor of restrictive defect in patients with MS. Our investigation also found significant correlations between delta FRC and delta BMI and between delta ERV and delta BMI. These results suggest that the BMI reduction induced by IGB was accompanied by increased FRC, most likely due to elevation of ERV. A reduced FRC is one of the main deleterious effects of obesity on lung function [34, 43–45]. Nevertheless, to the best of our knowledge, the present study is the first to show that the use of IGB in the treatment of obesity promotes a similar effect.

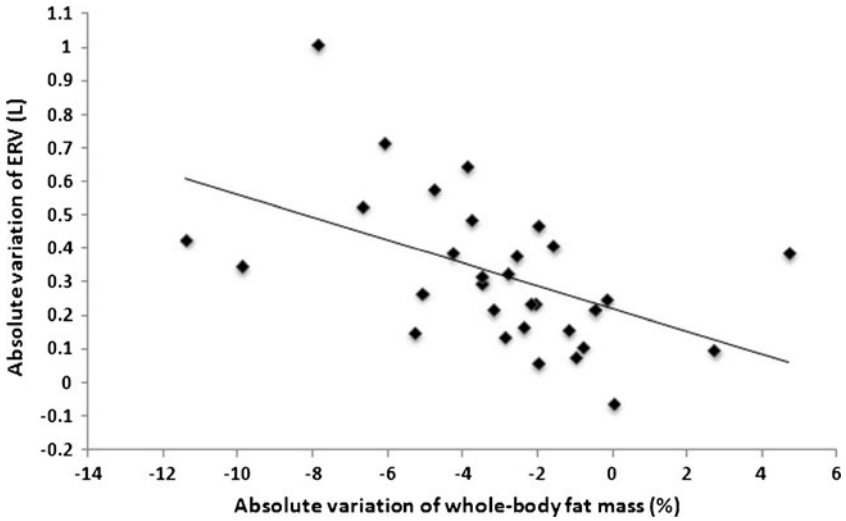

Fig. 5 Relationship of absolute variation of expiratory reserve volume (*ERV*) with absolute variation of whole-body fat mass over a 6-month period (ρ=−0.59; p= 0.0005); correlation was determined using Spearman's rank correlation

We also found significant correlations between the change in ERV and the changes in truncal, android, gynoid, and total fat. As mentioned above, fat deposition is one of the main mechanisms behind lung function impairment in obese people, particularly via reduction of ERV [43], suggesting that the progressive changes in ERV might be considered a 'biomarker' of the modifications that occur in the body composition during the use of IGB. Reduction of the trunk (truncal) or abdominal (android) fat was not the only finding that influenced the changes in ERV; in a separate analysis, the reduction of the fat percentage in the gynoid pattern exhibited a significant correlation with delta ERV. These results strengthen the hypothesis that the direct action of fat on respiratory mechanics is not the only cause of lung function impairment in obesity. It is likely that this correlation is also influenced by hormonal effects.

Our study has some limitations. First, it lacked a control group that did not receive an IGB, and the consistency of the results might have been enhanced by comparison with other weight loss methods. Second, DXA does not allow for a distinction between subcutaneous and visceral fat, which might have allowed for a more thorough analysis of the role of each type of fat in the present study. Third, the assessment ended upon removal of IGB. Future studies might assess these same outcomes after IGB removal. In spite of these limitations, we believe that our study represents an important contribution to this field, as no previous study has assessed the changes in lung function induced by IGB.

To conclude, the present study showed that the use of IGB in obese or overweight patients with MS promoted improvements of lung function parameters. In addition, IGB improved MS parameters as well as body composition as assessed by DXA. Therefore, the use of IGB was efficacious in inducing weight loss and simultaneous global improvement of the patients' state of health.

Conflict of Interest All contributing authors declare that they have no conflicts of interest.

References

1. Aballay LR, Eynard AR, Díaz Mdel P, et al. Overweight and obesity: a review of their relationship to metabolic syndrome, cardiovascular disease, and cancer in South America. Nutr Rev. 2013;71(3):168–79. Epub 2013 Jan 7. PMID 23452284.
2. World Health Organization. Obesity and overweight. Fact sheet no 311. 2013 http://www.who.int/mediacentre/factsheets/fs311/en/index.html. Accessed 8 Jan 2013
3. Brazilian Health Ministry. Almost half of the population is overweight. 2012. http://portalsaude.saude.gov.br/portalsaude/noticia/4821/785/quase-metade-da-populacao-brasileira-esta-acima-do-peso.html. Accessed 3 Apr 2013
4. Imaz I, Martínez-Cervell C, García-Álvarez EE, et al. Safety and effectiveness of the intragastric balloon for obesity: a meta-analysis. Obes Surg. 2008;18(7):841–6. PMID: 18459025.
5. Ladosky W, Botelho MAM, Albuquerque JP. Chest mechanics in morbidily obese non-hypoventilated patients. Respir Med. 2001;95(4):281–6. PMID: 11316110.
6. Koenig SM. Pulmonary complications of obesity. Am J Med Sci. 2001;321(4):249–79. PMID: 11307867.
7. Lin WY, Yao CA, Wang HC, et al. Impaired lung function is associated with obesity and metabolic syndrome in adults. Obesity (Silver Spring). 2006;14(9):1654–61. PMID: 17030977.
8. Mazess RB, Barden HS, Bisek JP, et al. Dual-energy X-ray absorptiometry for total-body and regional bone-mineral and soft-tissue composition. Am J Clin Nutr. 1990;51(6):1106–12. PMID: 2349926.
9. Mafort TT, Madeira M, Madeira M, et al. Intragastric balloon for the treatment of obesity: evaluation of pulmonary function over a 3-month period. Lung. 2012;190(6):671–6. Epub 2012 Sep 12. PMID: 22968677.
10. Santana H, Zoico E, Turcato E, et al. Relation between body composition, fat distribution, and lung function in elderly men. Am J Am J Clin Nutr. 2001;73(4):827–31. PMID: 11273860.
11. Wannamethee SG, Shaper AG, Whincup PH. Body fat distribution, body composition, and respiratory function in elderly men. Am J Clin Nutr. 2005;82(5):996–1003. PMID: 16280430.
12. Thomas PS, Cowen ERT, Hulands G, et al. Respiratory function in the morbidly obese before and after weight loss. Thorax. 1989;44(5):382–6. PMID: 2503905.
13. Alberti KG, Zimmet P, Shaw J. IDF Epidemiology Task Force Consensus Group. The metabolic syndrome: a new worldwide definition. Lancet. 2005;366(9491):1059–62. PMID: 16182882.
14. Zuccaro AM. A endoscopia digestiva alta na obesidade mórbida. Boletim da Sociedade Brasileira de Endoscopia Digestiva. 2013. http://www.sobedrj.com.br/areamedica.html#. Accessed 15 Feb 2013.
15. Pereira CAC, Rodrigues SC, Sato T. New reference values for forced spirometry in white adults in Brazil. J Bras Pneumol. 2007;33(4):397–406. PMID: 17982531.
16. Neder JA, Andreoni S, Peres C, et al. Reference values for lung function tests. I. Static volumes. Braz J Med Biol Res. 1999;32(6):703–17. PMID: 10412549.
17. Neder JA, Andreoni S, Peres C, et al. Reference values for lung function tests. III. Carbon monoxide diffusing capacity (transfer factor). Braz J Med Biol Res. 1999;32(6):729–37.
18. Neder JA, Andreoni S, Lerario MC, et al. Reference values for lung function tests. II. Maximal respiratory pressures and voluntary ventilation. Braz J Med Biol Res. 1999;32(6):719–27. PMID: 10412550.
19. Blouin K, Boivin A, Tchernof A. Androgens and body fat distribution. J Steroid Biochem Mol Bio. 2008;108(3–5):272–80. Epub 2007 Sep 7. PMID: 17945484.
20. Dumonceau JM. Evidence-based review of the Bioenterics intragastric balloon for weight loss. Obes Surg. 2008;18(12):1611–7. Epub 2008 Jun 21. PMID: 18568377.
21. Carvalho MR, Jorge Z, Nobre E, et al. Intra-gastric ballon in the treatment of morbid obesity. Acta Med Port. 2011;24(4):489–98. Epub 2011 Dec 12. PMID: 22521004.
22. Genco A, López-Nava G, Wahlen C, et al. Multi-centre European experience with intragastric balloon in overweight populations: 13 years of experience. Obes Surg. 2013;23(4):515–21. PMID: 23224509.
23. Lopez-Nava G, Rubio MA, Prados S, et al. BioEnterics® Intragastric Balloon (BIB®): single ambulatory center Spanish experience with 714 consecutive patients treated with one or two consecutive balloons. Obes Surg. 2011;21(1):5–9. Epub 2010 Mar 20. PMID: 20306153.
24. Mion F, Napoleon B, Roman S, et al. Effects of intragastric balloon on gastric emptying and plasma ghrelin levels in non-morbid obese patients. Obes Surg. 2005;15(4):510–6. PMID: 15946431.
25. Plank LD. Dual-energy X-ray absorptiometry and body composition. Curr Opin Clin Nutr Metab Care. 2005;8(3):305–9. PMID: 15809534.

26. Dulloo AG, Jacquet J, Solinas G, et al. Body composition phenotypes in pathways to obesity and the metabolic syndrome. Int J Obes (Lond). 2010;34 Suppl 2:S4–17. PMID: 21151146.
27. Dulloo AG, Montani JP. Body composition, inflammation and thermogenesis in pathways to obesity and the metabolic syndrome: an overview. Obes Rev. 2012;13 Suppl 2:1–5. PMID: 23107254.
28. Forlano R, Ippolito AM, Iacobelis A, et al. Effect of the BioEnterics intragastric balloon on weight, insulin resistance, and liver steatosis in obese patients. Gastrointest Endosc. 2010;71:927–33. Epub 2009 Oct 27. PMID: 19863955.
29. Mui WL, Ng EK, Tsung BY, et al. Impact on obesity-related illnesses and quality of life following intragastric balloon. Obes Surg. 2010;20(8):1128–32. PMID: 19015930.
30. Crea N, Pata G, Della Casa D, et al. Improvement of metabolic syndrome following intragastric balloon: 1 year follow-up analysis. Obes Surg. 2009;19(8):1084–8. Epub 2009 Jun 9. PMID: 19506981.
31. Despres JP, Lemieux I, Bergeron J, et al. Abdominal obesity and the metabolic syndrome: contribution to global cardiometabolic risk. Arterioscler, Thromb, Vasc Biol. 2008;28(6):1039–49. PMID: 18356555.
32. Dodson MV, Mir PS, Hausman GJ, et al. Obesity, metabolic syndrome, and adipocytes. J Lipids. 2011;2011:721686. PMID: 21811683.
33. Ye J. Emerging role of adipose tissue hypoxia in obesity and insulin resistance. Int J Obes (Lond). 2009;33(1):54–66. PMID: 19050672.
34. Lazarus R, Gore CJ, Booth M, et al. Effects of body composition and fat distribution on ventilatory function in adults. Am J Clin Nutr. 1998;68(1):35–41. PMID: 96655094.
35. Ray CS, Sue DY, Bray G, et al. Effects of obesity on respiratory function. Am Rev Respir Dis. 1983;128(3):501–6. PMID: 6614644.
36. Jenkins SC, Moxham J. The effects of mild obesity on lung function. Respir Med. 1991;85(4):309–11. PMID: 1947368.
37. Chen Y, Rennie D, Cormier YF, et al. Waist circumference is associated with pulmonary function in normal-weight, overweight, and obese subjects. Am J Clin Nutr. 2007;85(1):35–9. PMID: 17209174.
38. Dixon AE, Lundblad LK, Suratt BT. The weight of obesity on lung health. Pulm Pharmacol Ther. 2013. doi:10.1016/j.pupt.2013.03.017. PMID: 23548771.
39. Medoff BD. Fat, fire and muscle—the role of adiponectin in pulmonary vascular inflammation and remodeling. Pulm Pharmacol Ther. 2013;26(4):420-426. PMID: 22750271
40. Konter J, Baez E, Summer RS. Obesity: "Priming" the lung for injury. Pulm Pharmacol Ther. 26(4):427-429. doi: 10.1016/j.pupt.2012.03.003. PMID: 22449512
41. Salome CM, King GG, Berend N. Physiology of obesity and effects on lung function. J Appl Physiol. 2010;108(1):206–11. PMID: 19875713.
42. Klein S, Allison DB, Heymsfield SB, et al. Waist circumference and cardiometabolic risk: a consensus statement from shaping America's health: Association for Weight Management and Obesity Prevention; NAASO, the Obesity Society; the American Society for Nutrition; and the American Diabetes Association. Obesity (Silver Spring). 2007;15(5):1061–7. PMID: 17455180.
43. Jones RL, Nzekwu MMU. The effects of body mass index on lung volumes. Chest. 2006;130(3):827–33. PMID: 16963682.
44. Luce JM. Respiratory complications of obesity. Chest. 1980;78(4):626–31. PMID: 6998667.
45. Ochs-Balcom HM, Grant BJ, Muti P, et al. Pulmonary function and abdominal obesity in the general population. Chest. 2006;129(4):853–62. PMID: 16608930.