

EFFECT OF OBESITY ON LUNG PHYSIOLOGY AND DISTURBANCES BEFORE AND AFTER BARIATRIC SURGERY

Rafael Batista Pereira*

Ivan Romero Rivera**

Zirlene Correia Toscano de Brito***

Maria Alayde Mendonça da Silva****

ABSTRACT

This work aims to compare spirometry data before and after bariatric surgery, as well as the frequency of lung disorders. An observational, retrospective and analytical cohort study was performed, through the selection of patients with a diagnosis of obesity and indication of bariatric surgery. The sample size consisted of 28 obese patients, of 23 were women and five were men, to analyze the variables through spirometry, following the ATS protocols, using the best breath of three and selecting the best results curves. After surgery, there was a significant improvement in lung volumes and capacity: Forced vital capacity (FVC), FVC / Forced Expiratory Volume in one second ratio (FVC / FEV1) and Expiratory Flow Peak (EFP) and the Forced Expiratory Volume in one second FEV1, these variables increased significantly. There was also a strong and significant correlation between weight loss and increased FVC / FEV1, and EFP. The Relative Risk for lung disorders was 2.8-fold more likely to develop pulmonary dysfunction in obese than non-obese (post-surgical) patients. Gastropasty improved lung physiology as well as reduced the frequency of disorders.

Keywords: Obesity. Weight loss. Bariatric surgery. Spirometry. Pneumopathies.

INTRODUCTION

Obesity is characterized by excessive accumulation of body fat in the human body; anatomically, can be classified as hyperplastic and hypertrophic. Hyperplastic obesity is when a person has an abnormally increased number of fat cells. A normal person has about 30 billion adipose cells, while an obese person with hyperplasia may have 42 to 106 billion of these cells. Hypertrophic obesity, in turn, is related to the increase in the size of existing cells, a situation triggered by high caloric intake and sedentary lifestyle⁽¹⁾.

Studies have shown that metabolic changes (dyslipidemia, diabetes mellitus), lung disorders, changes in lung volumes and capacity, obstructive sleep apnea, renal, biliary diseases and certain types of neoplasms, as well as cardiovascular diseases, systemic arterial hypertension and neurological diseases are associated with obesity^(1,2).

The clinical treatment of obesity with the use of diet, physical activity and psychotherapy is not always enough to determine the necessary weight loss, especially in severe obese patients. As a treatment strategy, bariatric surgery has become a

practicable option for determining great weight loss and body fat, with a significant reduction in obesity-related comorbidities mentioned earlier^(2,3).

In Brazil, there are few articles published in recent years evaluating the relationship between obesity and pulmonary functions in patients undergoing bariatric surgery and the risk of obesity associated with pulmonary disorders in patients undergoing spirometry examination, which determined the question that guides the present research: *To what extent does severe obesity influence mechanics and, consequently, pulmonary function as well as disorders associated with the respiratory system?*

The measurement of pulmonary function can be evaluated through spirometry, since it is the examination with greater precision and specificity that detects, in addition to lung volumes and capacity, also the speed with which the air is inspired or expired. In this way, the exam can evaluate the predicted value for each person, as well as monitor the evolution of these parameters after interventions. The interpretation of pulmonary volumes can assess pulmonary physiology, identifying changes in different phases of ventilation and also of forced pulmonary volumes⁽⁴⁾.

*Physiotherapist. Master in human nutrition, professor of the Faculdade Sete de Setembro, in the subjects of human anatomy and physiology. Paulo Afonso, BA, Brazil. E-mail: rafael_85@hotmail.com

**Doctor. Doctorate in Medicine. Adjunct professor of medicine at the Federal University of Alagoas (UFAL) in the medical clinic department. Maceió, Al, Brazil. E-mail: imivera@uol.com.br

***Graduated in Physical Education and Physiotherapy. Specialist in Strength training and physical conditioning. Recife, PE, Brazil. E-mail: zirlenebrito@hotmail.com

****Doctor. Doctorate in Medicine. Adjunct professor of medicine and of the master's degree in Human Nutrition at the Federal University of Alagoas and Faculty of human nutrition (UFAL/FANUT). Maceió, Al, Brazil. E-mail: malayde1@uol.com.br

This study addresses the relationship between obesity and respiratory system function through spirometry, the results of which may indicate dysfunction or pulmonary disturbance. This fact is of great significance, since it alerts the population to the unconventional effects of obesity, in addition to pointing out the already well-known risks for cardiovascular diseases (acute myocardial infarction, stroke, hepatic steatosis, among others).

The aim of the study is to compare spirometry data and the frequency of pulmonary disorders before and after bariatric surgery.

METHODOLOGY

A retrospective and analytical cohort study was performed. The patients had a diagnosis of obesity and indication of bariatric surgery, inserted in the Bariatric Surgery Program of the University Hospital Professor Alberto Antunes (HUPAA), of the Federal University of Alagoas, located in Maceió – AL.

Twenty-eight obese patients who had undergone bariatric surgery according to the technique of Fobi and Capella⁽⁵⁾ were evaluated from January 2009 to December 2012, who had, in the preoperative evaluation protocol, recommendations to perform spirometry before and after surgery. Thus, the data of the sample were justified by the convenience, having been collected and stored in a database, in the period mentioned above, in the pulmonology center, from the medical records, followed by the sector's routine for the evaluation of the pulmonary function.

Obesity was identified by the Body Mass Index (BMI), using the World Health Organization (WHO) criteria, also adopted in Brazil: Low Weight (BMI < 18.5 kg/m²), Normal Weight (BMI between 25 and 29.9 kg/m²), Grade I Obesity (BMI between 30 and 34.9 kg/m²), Grade II Obesity (BMI between 35 and 39.9 kg/m²), Grade III Obesity (BMI > 40 kg/m²). Severe obese patients were considered as superobese (BMI = 50 Kg/m²) and supersuperobese with BMI > 60 Kg/m². The anthropometric measures of weight and height to determine BMI were performed on a mechanical scale (anthropometric) with a maximum capacity of 300 kg in the model 104A (Adult), precision of 100 grams, platform 30 x 40 cm, Michelitti®, which has metric tape attached (stadiometer) for height measurement. To measure this, the patients were barefoot with their feet together and their backs binded to the stadiometer, the tape measure being positioned above their head⁽⁶⁾.

For the spirometric variables FEV₁, FVC/FEV₁, PEF, FVC, the criteria adopted by the American Thoracic Society^(6,7) were used. The normal pulmonary volumes, used as reference, were based on the validation of the new predicted values for each Brazilian person^(7,8).

Spirometry was performed by HUPAA's Pulmonology-Spirometry service, which works with the pulmonologists on duty at the hospital; Spirolab® III S/N 300243 instrument was used. The spirometry data and charts were based on the person's best values or the best composite curve, as well as on the choice of the best three-stroke to select the index. The flow/volume and volume/time curves for Forced Vital Capacity (FVC) in liters, Forced Expiratory Volume in 1 second in liters (FEV₁), the FEV₁/FVC ratio (%), peak expiratory flow in liter (PEF)^(7,8).

According to the time patients underwent spirometry after surgery, three groups were categorized as follows: the first group consisted of 14 patients who underwent spirometry before and "up to one year after surgery", on an average post-operative time of 6.1 months; the second consisted of 14 patients, who underwent spirometry before and "more than one year after surgery" and in average time of 1.8 years; In this way, we could analyze the effects of surgery on obese patients in the short and medium/long term; the third group, called the "general", consisted of all 28 patients included in the two previous groups, in order to test the effect of surgery independent of the postoperative period; the average follow-up time in the postoperative period was 1.3 years.

Regarding the normality assumption, the data were analyzed by the Shapiro Wilks test to verify the normal distribution of the variables data; those who had a normal distribution were submitted to the paired Student's test ($p \leq 0.05$), to compare the means of the pre x postoperative groups, and a linear regression analysis was performed to illustrate the correlation strength according to with the ratio (r) and the coefficient of determination by (r^2); the F test was used to determine the level of significance of the regression ($p \leq 0.05$). The variables FEV₁ and FVC did not present normality regarding the distribution of the data.

For the non-parametric data, the Wilcoxon Signed Rank Test ($p \leq 0.05$) was used to compare the paired means and Spearman's Rho correlation (r), which determines the correlation between weight loss and variations in lung volumes. Only statistically

significant data were transformed into figures.

To evaluate the Relative Risk, the group of exposed (obese before surgery) versus non-exposed (non-obese after surgery) and pulmonary disorders were tested through spirometry. A Confidence Interval (CI) of 95% was adopted.

The pairing (paired samples) of the groups under test, for the mean of the variables, was given to the categorized group, in the case: "before" and "after" surgery, in which the variable response consisted of the data values of the spirometry. There were no losses in follow-ups or outliers.

For the coefficient of determination of R^2 , the following values were observed: $R^2 = 0$ no correlation, <0.4 weak correlation, <0.7 moderate correlation, from 0.7 to <1.0 strong correlation and equal to one (1) perfect correlation. These values were applied in Spearman's Pearson and Rhô correlation. All statistical analyzes were performed using the SPSS Statistics for Windows program, version 22.0⁽⁹⁾.

The research project was approved by the Research Ethics Committee of the Federal University

of Alagoas, under the opinion number 09986212.1.0000.2013. All participants signed the informed consent form (TCLE).

RESULTS

The study participants were composed of five men and 23 women, aged between 29 and 55 years (mean age 42.2 years and median age 41.5 years). The BMI, before surgery, varied between 40.8 and 58.4 kg/m², Mean of 47.5 kg/m² and Mean of 47 kg/m².

All patients who underwent surgery and were followed up during the postoperative period improved the degree of obesity by 100%, progressing to the normal or overweight range.

Table 1 shows the comparison of the mean volume and lung capacity between the preoperative and postoperative groups, which were divided into three subgroups, categorized according to each evaluated variable. It was still possible to observe how much, in percentage, the patients improved the pulmonary function, by spirometry, after the surgery.

Table 1. Descriptive Statistics Summary of the spirometric variables of 28 individuals (mean, standard deviation and difference between means in percentage -%) - obtained in the pre and postoperative period of bariatric surgery. HUPAA's Pulmonology Center from 2009 to 2012

Variables	GENERAL			< 1 YEAR			> 1 YEAR		
	Pre	Post	Difference (%)	Pre	Post	Difference (%)	Pre	Post	Difference (%)
FVC	2.59 ± 4.6	2.63 ± 4.8*	1.5 %	2.53 ± 3.4	2.55 ± 3.2	0.8 %	2.66 ± 0.5	2.72 ± 0.6**	2.3 %
FVC/FEV1	80 ± 4.3	84 ± 4.4**	5.0	80 ± 4.4	84 ± 4.3**	5.0	83 ± 4.2	86.5 ± 5.3**	4.5
PEF	4.5 ± 1.1	4.9 ± 1.2 1**	9.0	4.51 ± 0.8	4.9 ± 0.8**	8.6	4.5 ± 1.6	5 ± 1.5**	11.0
FEV1	2.27± 0.45	2.29 ± 0.47	0.8	2.19 ± 0.4	2.2 ± 0.39	0.9	2.2 ± 0.49	2.4 ± 0.5*	7.1

General group = 28 patients who underwent spirometry, regardless of the time of post; Subgroup up to 1 year = 14 patients who underwent spirometry up to 1 year of post; Subgroup older than 1 year = 14 patients who underwent spirometry after 1 year of surgery.

* Indicates significance ≤ 0.01 ;

** Indicates significance ≤ 0.05 .

All four variables evaluated - FVC, FVC/FEV1, PEF and FEV1 - achieved an increase in lung volumes after gastropasty. For the FVC variable data, there was a significant difference in the general group ($p=0.027$) and in the FVC subgroup greater

than one year ($p=0.014$). For the variable FVC/FEV1, a significant difference was observed in all groups - general FVC, up to 1 year and greater than 1 year in the post-time period, which improved with $p = 0.00043$, 0.003 , 0.007 , respectively. The PEF also

improved after surgery in all three groups, with a level of significance $p = 0.0001$, 0.014 , 0.009 , respectively. For FEV1, only the “more than one year” postoperative subgroup had significant alterations ($p = 0.05$).

A correlation was made between weight loss and spirometric data variation, both in percentage. In Figure 1, it was verified that the two variables FVC/FEV1 and PEF pointed to a positive r^2 , which indicates that, as there is weight loss, there is variation

in the pulmonary volume gain. The coefficient of determination of weight loss, by BMI versus FVC/FEV1, indicated that 70% of the variation in weight loss correlated with the gain in lung volumes and, for PEF, indicated a correlation of 68%.

Table 2 summarizes the values found in the regression line “ r^2 ” and the correlation force “ r ”, as well as the adjustment of the regression model. Regarding BMI and FVC, FVC/FEV1 and PEF, all presented a strong correlation, statistically significant.

Table 2. Correlation and Regression between weight loss after BMI surgery (%) x Difference between the mean of the spirometric variable pre x postoperative (%).

Dados	R ²	R	Modelo
BMI x FVC		$r = 0,77^{**}$ (spearman)	
BMI x FEV1		$r = 0,235$ (spearman)	
BMI x FVC/FEV1	$R^2 \text{ linear} = 0,68$	$r = 0,832^{**}$	$Y = -13,78 + 0,39 \cdot x$
BMI x PEF	$R^2 \text{ linear} = 0,67$	$r = 0,822^{**}$	$Y = -28,26 + 0,82 \cdot x$

R^2 = Determination coefficient; r = Correlation coefficient; Y = regression model; * indicates p significance = 0.01; ** indicates p significance = 0.05; Absence * indicates that there was no significant difference between the groups.

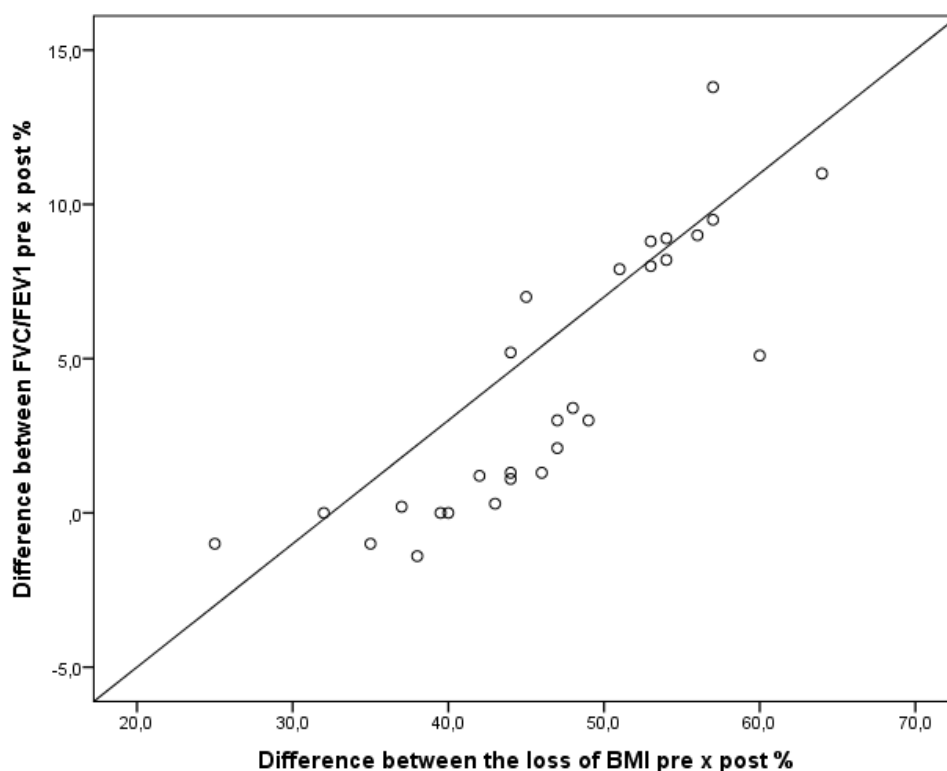


Figure 1 – Simple linear regression curve between percent change of FVC/FEV1 and weight loss by BMI.

In relation to pulmonary disorders diagnosed by spirometry, 14 pulmonary disorders were present in 28 patients before surgery; of these, only one patient had previous lung disease and eight were smokers. After surgery, only four

disorders of the preexisting 14 remained, indicating a reduction of 71.4%. Of the 14 preexisting disorders presented, 12 were of the restrictive type, one obstructive and one mixed (obstructive + restrictive). Table 3 shows the

calculated Relative Risk data, as well as CI, in which patients who had previous lung disorders or were smokers were excluded; it was observed that the 2.8-fold higher risk was for the obese to

develop some type of pulmonary disorder, be it restrictive, obstructive or mixed, and CI showed that the result was statistically significant.

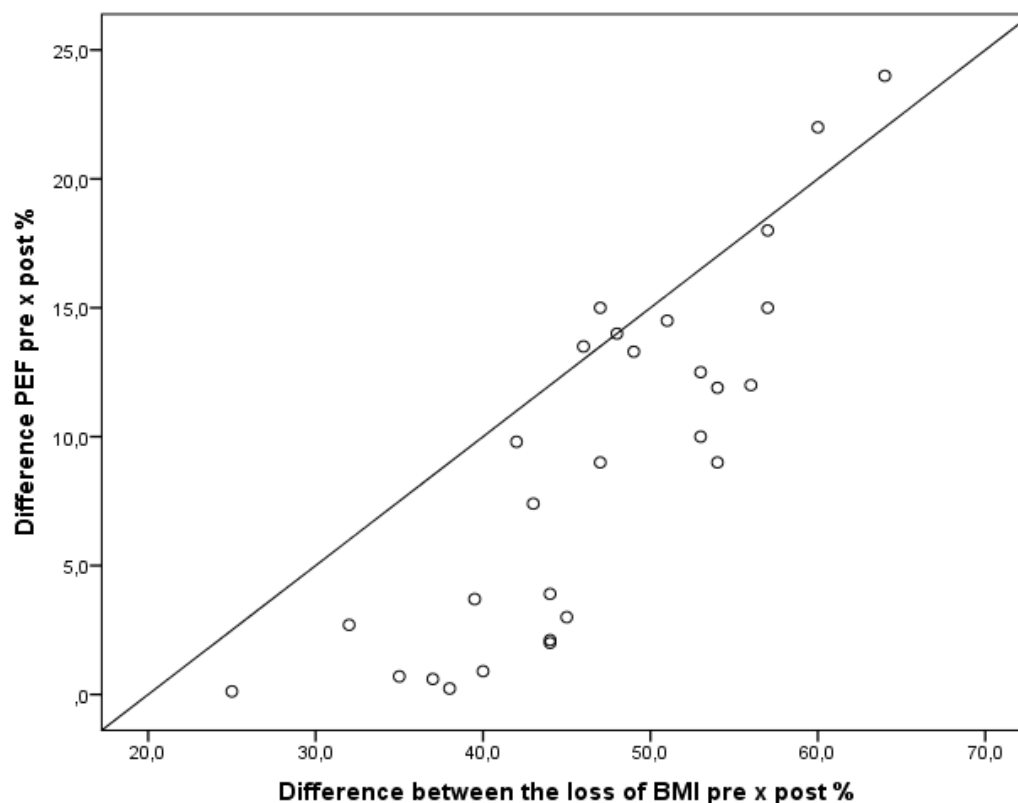


Figure 2. Simple linear regression curve between percent change in PEF and weight loss.

Figures 1 and 2 illustrate the scatter chart associated with the simple linear regression line, where the Y axis demonstrates the dependent variable (percentage concerning PEF change after surgery) and the X axis is the independent variable (percentage

of loss of weight after surgery). In both figures, it was observed that, as weight loss occurred, there was an increase in lung volume for PEF and the ratio between FVC/FEV 1, both statistically significant.

Table 3. Distribution of the number of patients according to obesity and the presence or absence of pulmonary disorders, Relative Risk and Confidence Interval (95%).

Obesity	Pulmonary Disorder		
	Yes	No	Total
Yes	8	11	19
No	4	23	27
Total	12	34	46
RR	2,8		
CI	1,12 – 13,4		

DISCUSSION

Three different studies evaluating pulmonary function through spirometry, with follow-up up to

one year after surgery, showed a significant improvement in FVC, FEV1 and FVC/FEV1, as was observed in this study. Rapid weight loss beneficially alters pulmonary mechanics, allowing better

gradilcostal expansion and better diaphragmatic activity and intercostal muscles. Such changes improve the ability of the respiratory system to perform gas exchange, which depends on factors such as the diaphragm and thoracic muscles, which should be able to expand the chest and lungs to produce subatmospheric pressure⁽¹⁰⁻¹³⁾.

One study investigated the frequency of pulmonary dysfunctions in 30 patients, observing that eight had pulmonary dysfunction before surgery, four of which were restrictive and four were obstructive; after surgery, there was improvement in 100% of the patients⁽¹²⁾. During the present study, there was also improvement in lung disorders, with a reduction in their frequency after surgery. As such disorders are dependent on lung volumes and capacity, when there is improvement in lung volumes and capacity, they are corrected accordingly.

The results above demonstrate that obesity negatively interferes with lung function (quantified by spirometry) and that weight loss determined by bariatric surgery, evaluated at present and in other studies, about one year after surgery, results in significant improvement in values, demonstrating a rapid adaptation of the organism to weight loss⁽¹⁰⁻¹³⁾.

In a study that tracked 15 women undergoing gastropasty and who underwent spirometry one month before surgery and two years later, a significant increase in FEV1 and FVC ($p \leq 0.01$) was observed⁽¹⁴⁾. There, an increase in FVC was identified for the general group, and for the group that underwent spirometry with more than one year postoperatively, as well as FEV1, both significantly.

In a long-term study, with a five-year follow-up after surgery, in which the authors separated the groups composed of 80 women and 21 men, it was observed that the lung volumes evaluated, the same as in the present study, were FEV1 and FVC. For the group of women, in this study, FEV1 increased significantly, 4.1% ($p \leq 0.001$) and 6.7% in men ($p = 0.003$). The FVC variable also showed a significant increase in both groups, for women 5.8% ($p \leq 0.001$) and 7.6% for men ($p \leq 0.001$). These same variables obtained a significant increase in this study for the group that underwent spirometry after one year of surgery⁽¹⁵⁾. This was the study with the longest recorded follow-up; it identified a persistence of the improvements found after surgery in some of the variables tested, which means that these groups of patients adapt well to the anatomical-functional change determined by weight loss, maintaining it for

a long period.

In some of these studies, the frequency of pulmonary dysfunctions diagnosed by spirometry was also evaluated and a reduction in the frequency of dysfunctions after surgery was observed, an expected result, since the improvement in pulmonary volumes tends to correct the dysfunction itself. Increased body mass results in increased oxygen consumption and carbon dioxide production, leading to respiratory complications that are twice as frequent in obese as non-obese. This fact implies the presence of lung disorders prior to surgery and the reduction of their frequency after weight loss. These results corroborate the findings of this study, that there is a 2.8-fold increased risk for obese patients presenting with pulmonary disorders in relation to non-obese patients^(14,16,17).

In a study of 55 obese patients, subdivided into two groups, according to BMI, it was observed that in both groups, the proportion with significant restrictive pulmonary dysfunctions was similar. These results are equivalent to that of the present study, indicating that obese patients commonly develop a larger quantity of obstructive-type disorders and a smaller amount of restrictive type⁽¹⁸⁾.

The alteration in ventilatory kinetics seems to have also had an effect on expiratory force, since the present study and the others cited demonstrate changes in expiratory lung volume in obese patients. The expiratory force depends on the abdominal muscles and the internal intercostals and the excess weight can also alter the mechanics of the abdominal and intercostal muscles, so some patients can suffer reduction in the lung volume, both inspiratory and expiratory⁽¹³⁻¹⁸⁾.

Pulmonary function undergoes major changes in obese persons, which are proportional to the degree of obesity presented. In our study, a direct correlation was made between weight loss, given by BMI in percentage - % - and gain in lung volume, also in percentage - % - pointing to a significant improvement in three of the four variables evaluated. Pulmonary volumes and capacity, in most of these patients, demonstrate a restrictive and/or obstructive respiratory pattern in airflow⁽¹⁹⁾. Morbid obesity and fat accumulation contribute to the hypoventilation syndrome, resulting in altered lung volumes and increased airflow resistance and respiratory work, that is, the greater the degree of obesity, the greater the impairment⁽¹⁸⁾.

A correlation between weight loss and lung

volume gain was observed in a study of 20 patients who had a moderate and significant correlation force in PEF ($r=0.55$ and $p<0.01$)(20), as well as in our study with PEF, a strong and significant correlation was also found, but no significant correlation was found with FVC/FEV1 and FVC; unlike our study, those results may have occurred due to the relatively low number of patients in whom the statistical analyzes become quite rigorous, or are simply performed at random⁽²⁰⁾.

In Brazil, few studies have been conducted to evaluate the risk of obesity regarding changes in pulmonary function assessed by spirometry. Thus, the analysis of the PEF variable was not tested in studies, comparing the mean of groups after weight loss by surgery; this is important because this variable

is able to predict the rate at which the individual can expel the air, resembling FEV1, and through it, the "burst" force of the expiratory muscles can be measured, which indicates obstruction of airflow⁽¹³⁾.

CONCLUSION

Weight loss, determined by bariatric surgery, resulted in improved pulmonary function assessed by spirometry, as well as reduced frequency of pulmonary disorders. Severe obese patients are about six times more likely to develop pulmonary dysfunction than non-obese patients. The results found in the present study demonstrated that, as there is weight loss, there is also a gain in lung volume.

EFEITO DA OBESIDADE NA FISILOGIA E DISTÚRBO PULMONAR ANTES E APÓS A CIRURGIA BARIÁTRICA

RESUMO

O estudo teve por objetivo comparar os dados da espirometria e da frequência de distúrbios pulmonares antes e após a cirurgia bariátrica. Realizou-se estudo observacional de coorte, retrospectivo e analítico, de uma amostra de pacientes com diagnóstico de obesidade e indicação de gastroplastia. Os dados da amostra constituíram-se de 28 obesos, dos quais 23 eram mulheres e cinco eram homens, para a análise das variáveis através da espirometria, em que foram seguidos os protocolos da ATS, utilizando-se o melhor sopro de três e as melhores curvas dos resultados. Após a cirurgia, observou-se uma melhora significativa na Capacidade Vital Forçada (CVF), na Capacidade Vital Forçada/Volume Expiratório no 1º segundo (CVF/VEF1), no Pico de Fluxo Expiratório (PFE) e no Volume Expiratório Forçado no 1º segundo (VEF1). Também se observou uma forte correlação entre a perda de peso e as CVF/VEF1 e PFE. Verificou-se um Risco Relativo de 2,8 vezes maior de desenvolvimento de distúrbios pulmonares em obesos do que em não obesos (pacientes pós-cirúrgicos). Concluiu-se que a gastroplastia melhorou a função pulmonar, bem como reduziu a frequência dos distúrbios respiratórios após a cirurgia.

Palavras-chave: Obesidade. Perda de peso. Cirurgia bariátrica. Espirometria. Pneumopatias.

EFFECTO DE LA OBESIDAD EN LA FISIOLÓGIA Y DISTURBIO PULMONAR ANTES Y DESPUÉS DE LA CIRUGÍA BARIÁTRICA

RESUMEN

El estudio tuvo el objetivo de comparar los datos de la espirometría y de la frecuencia de distúrbios pulmonares antes y después de la cirugía bariátrica. Se realizó estudio observacional de cohorte, retrospectivo y analítico, de una muestra de pacientes con diagnóstico de obesidad e indicación de gastroplastia. Los datos de la muestra se constituyeron de 28 obesos, de los cuales 23 eran mujeres y cinco eran hombres, para el análisis de las variables a través de la espirometría, en que fueron seguidos los protocolos de la ATS, utilizándose el mejor sopro de tres y las mejores curvas de los resultados. Tras la cirugía, se observó una mejora significativa en la Capacidad Vital Forzada (CVF), en la Capacidad Vital Forzada/Volumen Expiratorio en el 1º segundo (CVF/VEF1), en el Pico de Flujo Expiratorio (PFE) y en el Volumen Expiratorio Forzado en el 1º segundo (VEF1). También se observó una fuerte correlación entre la pérdida de peso y los CVF/VEF1 y PFE. Se verificó un Riesgo Relativo de 2,8 veces mayor de desarrollo de distúrbios pulmonares en obesos que en no obesos (pacientes posquirúrgicos). Se concluye que la gastroplastia mejoró la función pulmonar, así como redujo la frecuencia de los distúrbios respiratorios tras la cirugía.

Palabras clave: Obesidad. Pérdida de peso. Cirugía bariátrica. Espirometría. Pneumopatias.

REFERENCES

1. Machado IE, Pereira SCL, Júnior CS, Abreu MNS, Borges AM, Filgueiras JL. Factors associated with being overweight among adults using low-budget restaurants in Belo Horizonte, Brazil. *Ciênc Saúde Coletiva* [online]. 2014 Mar [citado em 05 de mar 2018]; 19(5):

1367-1377. doi: <http://dx.doi.org/10.1590/1413-81232014195.21772013>.

2. Cattai GB, Rocha F, Hintze LJ, Pagan BG, Junior NN. Multiprofessional treatment program of the obesity: the challenges of the practice. *Ciênc Cuid Saúde* [online]. 2008 Mar [citado em 05 de mar 2018]; 7(1): 121-126. doi:

- <http://dx.doi.org/10.4025/ciencucidsaude.v7i0.6582>.
3. Batalha SB, Bendall AL, Fijtman A, Bissella AC, Pilz K, Walz JC. Analysis of the correlation between three anthropometric measures of body weight in schoolchildren. *Cienc Cuid Saude* [online]. 2017 Julh/Setembro [citado em 25 de mar 2018]; 16(3): 1-7. doi: <http://dx.doi.org/10.4025/ciencucidsaude.v16i3.31603>.
 4. Huisstede AV, Biter LU, Luitwieler R, Cabezas MC, Mannaerts G, Birnie E. et al. Pulmonary Function Testing and Complications of Laparoscopic Bariatric Surgery. *Obes Surg* [online]. 2013 Oct [citado em 04 de mar 2018]; 23(10): 15-23. doi: <http://doi.org/10.1007/s11695-013-0928-9>.
 5. Tremaroli V, Karlsson F, Werlin M, Stahlman M, Kovatcheva-Datchary P, Olbers T. et al. Roux-en-Y Gastric Bypass and Vertical Banded Gastroplasty Induce Long-Term Changes on the Human Gut Microbiome Contributing to Fat Mass Regulation. *Cell Metabolism Clinical & Translational Report* [online]. 2015 Aug [citado em 05 de Mar 2018]; 14(15): 228-238. doi: <http://dx.doi.org/10.1016/j.cmet.2015.07.009>.
 6. Toro LZ, Tovar JR, Giner L, González J, Aguilar MM, García A. et al. Assessment of cardiovascular risk after sleeve gastrectomy: comparative of BMI, adiposity, Framingham and atherogenic index as markers of success of surgery. *Nutrición Hospitalaria* [online]. 2016 Mar [citado em 05 de Mar 2018]; 33(4): 832-837. doi: <http://dx.doi.org/10.20960/nh.377>.
 7. Duarte AAO, Pereira CAC, Rodrigues SCC. Validation of new Brazilian predicted values for forced spirometry in Caucasians and comparison with predicted values obtained using other reference equations. *J Bras Pneumol* [online]. 2017, jan [citado em 05 de Mar 2018]; 33(5): 527-535. doi: <http://dx.doi.org/10.1590/s1806-37132007000500007>.
 8. Johnson JD, Theurer WM. A Stepwise Approach to the Interpretation of Pulmonary Function Tests. *American Family Physician* [online]. 2014 Mar [citado em 05 de Mar 2018]; 89(5): 359-366. Available in: <https://www.aafp.org/afp/2014/0301/p359.pdf>.
 9. Glantz SA. "Princípios de Bioestatística. 7a ed. Porto Alegre: Artmed; 2014.
 10. Sebanne M, Kamel ME, Millot A. Effect of Weight Loss on Postural Changes in Pulmonary Function in Obese Subjects: A Longitudinal Study. [online]. 2015 July [citado em 05 Mar 2018]; 60(7): 992-999. doi: <http://doi.org/10.4187/respcare.03668>.
 11. Barbalho-Moulim MC, Miguel GPS, Forti EMP, Campos FA, Peixoto-Souza FS, Costa D. Pulmonary Function after Weight Loss in Obese Women. *ISRN Obesity* [online]. 2013 Jan [citado em 05 Mar 2018]; 2013(1): 1-5. doi: <http://dx.doi.org/10.1155/2013/796454>.
 12. Cervantes AD, Cherit GD, Borunda D, Gamino R, Vargas-Vorackova F, González-Barranco J. Impact of Surgically-Induced Weight Loss on Respiratory Function: A Prospective Analysis. *Obesity Surgery*. [online]. 2004 Nov-Dec [citado em 05 Mar 2018]; 14(10): 1389-1392. doi: <http://doi.org/10.1381/0960892042583996>.
 13. Giesler A, Mukherjee M, Radford K, Janssen L, Nair P. Modulation of human airway smooth muscle biology by human adipocytes. *Respiratory Research* [online]. 2018 Jan [citado em 04 de mar 2018]; 19(33): 1-9. doi: <http://doi.org/10.1186/s12931-018-0741-z>.
 14. Santiago A, Carpio C, Caballero P, Martín-Duce A, Vesperinas G, Terreros FG. Effects of weight loss after bariatric surgery on pulmonary function tests and obstructive sleep apnea in morbidly obese women. *Nutrición Hospitalaria* [online]. 2015 Sep [citado em 05 de mar 2018]; 32(3): 1050-1055. doi: <http://doi.org/10.3305/nh.2015.32.3.9487>.
 15. Hewitt S, Humerfelt S, Søvik TT, Aasheim ET, Ristad H, Kristinsson J. Long-term improvements in pulmonary function 5 years after bariatric surgery. *Obes Surg* [online]. 2014 May [citado em 05 de mar 2018]; 24(5): 1159-1166. doi: <http://dx.doi.org/10.1007/s11695-013-1159-9>.
 16. Valenza F, Froio S, Coppola S, Vagginelli F, Tiby A, Marengi MC. Preoperative changes of forced vital capacity due to body position do not correlate with postoperative respiratory function in obese subjects. *Minerva Anestesiologia* [online]. 2013 April: [citado em 06 de mar 2018]; 79(4): 342-348. Available in: <https://www.minervamedica.it/en/journals/minerva-anestesiologica/article.php?cod=R02Y2013N04A0342>.
 17. Xavier MAF, Ceneviva R, Filho JT, Sankarankutty AK. Pulmonary function and quality of life in patients with morbid obesity six months after. *Acta Cirúrgica Brasileira* [online]. 2010 May: [citado em 06 de mar 2018]; 25(5): 407-415. doi: <http://dx.doi.org/10.1590/S0102-86502010000500005>.
 18. Guimarães C, Martins MV, Moutinho SJ. Pulmonary Function Tests in Obese People Candidate to Bariatric Surgery. *Rev Port Pneumol* [online]. 2012 May – Jun [citado em: 06 mar 2018]; 18(3): 115-119. doi: <http://doi.org/10.1016/j.rppneu.2012.01.005>.
 19. Clavellina-Gaytán D, Velázquez-Fernández D, Del-Villar E, Domínguez-Cherit G, Sánchez H, Mosti M. Evaluation of spirometric testing as a routine preoperative assessment in patients undergoing bariatric surgery. *Obes Surg*. [online]. 2015 Mar; [citado em 06 mar 2018]; 25(3): 530-536. doi: <http://doi.org/10.1007/s11695-014-1420-x>.
 20. Bhammar DM, Stickford JL, Bernhardt V, Babb TG. Effect of weight loss on operational lung volumes and oxygen cost of breathing in obese women. *Nature Journal of Obesity* [online]. 2016 Feb; [citado em 06 mar 2018]; 40(6): 998-1004. doi: <http://doi.org/10.1038/njo.2016.21>.

Corresponding author: Rafaell Batista Pereira. Rua: Dr. Antônio Cansação, nº 657, Bairro: Ponta Verde, Cep: 57035-190, Maceió – Alagoas. E-mail: Rafaell_85@hotmail.com. Telephone: (82) 99952 6844

Submitted: 24/11/2017

Accepted: 30/03/2018