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Slow Vital Capacity: Differences Between the Expiratory Vital Capacity and the Inspiratory Vital Capacity

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ABSTRACT

Introduction: The vital capacity (VC) can be determined by means of the expiratory vital capacity (EVC) or the inspiratory vital capacity (IVC). Obtaining the highest VC volume is essential for the correct interpretation of lung function tests.
Objectives: To determine the differences between the EVC and the IVC (EVC-IVC) according to the ventilatory pattern; to characterize the FEV_1/EVC and FEV_1/IVC ratios when an obstruction of the airways is detected; to study the effects of the EVC or IVC on the detection of air trapping or lung hyperinflation.
Materials and Methods: Cross-sectional study. The sample included 388 individuals divided in 3 groups: healthy, airway obstruction, and restrictive lung disease. In order to detect the airway obstruction, we studied the FEV_1/EVC and FEV_1/IVC ratios. The presence of air trapping or lung hyperinflation was determined by means of a lung volume test. The differences between the EVC and the IVC (EVC-IVC) according to the ventilatory pattern were grouped into classes.
Results: In the normal group, there was an EVC-IVC difference of ≥ 200 ml in 34.8% of the individuals; in the airway obstruction group, 28.4%, and in the restrictive lung disease group, 22.4%. The FEV_1/EVC ratio detected airway obstruction in 44.8% of the individuals, and the FEV_1/IVC ratio in 39.4%. In patients with airway obstruction, the EVC maneuver determined the presence of air trapping in 21.6% of subjects and lung hyperinflation in 9.5%. The IVC maneuver showed 18.2% and 10.8%, respectively.
Conclusions: The EVC and IVC should not be used as interchangeable maneuvers, considering the volume differences obtained with each one of them. Their results influenced the interpretation of lung function.

Key words: Respiratory function testing; Measurement of lung volume; Vital capacity; Airway obstruction; Lung capacity

Introduction

Vital capacity (VC) can be measured forcibly (forced vital capacity, FVC) or slowly (slow vital capacity, SVC), the latter being determined through the expiratory vital capacity (EVC) or the inspiratory vital capacity (IVC)[1]. The VC is influenced by the airway caliber and determining factors in total lung capacity (TLC) and residual volume (RV)[2].

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Even though Hutchinson[3] defined the VC as the maximum volume of expired gas after a maximun inspiration (EVC), and it is the most commonly used method, the maneuver is frequently performed inversely (IVC). It is reasonable to expect similar VCs obtained through both the inspiratory and expiratory maneuvers; however, differences were observed in some individuals with pulmonary emphysema[4].

The VC analysis is essential for the interpretation of lung function tests results. The correct determination of the VC is fundamental to the calculation of the TLC; also, its partial flow conditions the value of the RV and, consequently, of the TLC, preventing the detection of air trapping, lung hyperinflation and restrictive lung disease[5-7].

The VC is also important to determine the presence of airway obstruction; according to the American Thoracic Society/European Respiratory Society (ATS/ERS)[8], the presence of this type of ventilatory defect is defined by the decrease in the ratio between the maximum expiratory volume in the first second and the greatest vital capacity (FEV_1/VC). The denominator in this ratio may include the forced vital capacity (FVC) or the slow vital capacity (SVC) (EVC or IVC), depending on which has the highest volume[9].

Once the SVC can be determined by the EVC or the IVC, it is considered very important to understand which one of these methodologies allows for the highest volume, given that the VC is usually obtained through one of them and not both. So, the FEV_1/EVC or the FEV_1/IVC ratio can be used, where the most sensitive to the detection of an airway obstruction is that which includes the larger denominator.

The objectives of this study were: 1) to determine the differences between the EVC and the IVC (EVC-IVC) according to the ventilatory pattern; 2) to characterize the FEV_1/EVC and FEV_1/IVC ratios and their capacity of detection of an airway obstruction; 3) to study the consequences of performing the EVC or IVC in the detection of air trapping or lung hyperinflation; 4) to understand the impact of the EVC or IVC on the degree of severity of the restrictive lung disease; 5) to verify the existence of an association between the EVC-IVC parameter and the FEV_1, TLC, RV and FRC (functional residual capacity) variables.

Materials and Methods

The study is prospective, quantitative and cross-sectional. The sample consists of individuals who underwent lung function tests between January and June 2017 at the Respiratory Physiopathology Unit of the Hospital Pulido Valente - Centro Hospitalar Universitário Lisboa Norte – Portugal. The research was approved by the Ethics Committee of the Centro Hospitalar Universitário Lisboa Norte and the Lisbon Academic Medical Center.

The inclusion criteria were age > 18 years and internal prescription of functional respiratory tests, including spirometry and whole-body plethysmography. The exclusion criteria were: non-compliance with the quality standards established by the ATS/ERS[1,10] rules; having underwent inhalation therapy before the tests; the presence of mixed ventilatory defects and air trapping or lung hyperinflation criteria in the absence of airway obstruction.

The individuals went to the Unit to perform lung function tests, and the objective of the research has been explained to them. We verified inclusion and exclusion criteria in those individuals who accepted to participate in the study. The ones who were eligible were given an informative document. After reading it, those who agreed with the terms of the study signed an informed consent. The sample consisted of 388 individuals. The equipment used in this study was a *Sensormedics® Vmax Series Autobox 6200* plethysmograph (Yorbalinda, California, USA, 1998), calibrated daily in accordance with the manufacturer's rules. The reference equations used for the tests have been proposed by the European Community for Coal and Steel[11]. The respiratory function tests comply with the guidelines proposed by the ATS/ERS (Standardisation of Spirometry[1] and Standardisation of Measurement of Lung Volumes[10].

The first technique was the whole-body plethysmography to obtain the SVC through the EVC and IVC. Three reproducibility attempts were made with a minimum interval of three minutes between each. In one half of the sample, we first determined the EVC (three EVC maneuvers) and immediately after that, the IVC was determined (three IVC maneuvers). In the other half, we followed the opposite procedure. The final value of the variables was the average of the three reproducibility attempts. The spirometry was performed after the plethysmography, avoiding the potential muscle fatigue and the volume history[1]. A three-minute interval was established between techniques.

The parameters acquired by the whole-body plethysmography were shown taking into account the type of SVC maneuver that was performed, that is to say, calculating the average of each group of three EVC and IVC maneuvers, and showing each one of the variables.

The airway obstruction has been defined by FEV_1/FVC, FEV_1/EVC and $FEV_1/IVC < 0.70$, and five degrees of severity have been considered in accordance with the ATS/ERS[8]. The restrictive lung disease was determined by the existence of a TLC < 80% and was classified, according to Mottram[7], into three degrees of severity. The TLC, taken into account for the definition of the ventilatory pattern and degree of severity of the underlying restrictive lung disease has been obtained considering the mean value of the EVC and IVC maneuvers. Subsequently, a subanalysis was made in relation to the degree of severity of the restrictive lung disease, according to the type of expiratory maneuver that was performed (EVC or IVC), based on the TLC_{EVC} and TLC_{IVC}.

The presence of RV_{EVC} or RV_{IVC} > 140%, FRC_{EVC} or FRC_{IVC} > 120% and TLC_{EVC} or TLC_{IVC} < 120% was considered air trapping, and RV_{EVC} or RV_{IVC} > 140%, FRC_{EVC} or FRC_{IVC} > 120% and TLC_{EVC} or TLC_{IVC} ≥ 120% were considered lung hyperinflation.

To complete the characterization of the differences between the EVC and IVC according to the ventilatory pattern, we made a subanalyisis that classified those differences in three classes: 1) EVC-IVC (L-liters) ≤ 100 (ml-milliliters); 2) EVC-IVC (L) ≤ 200 ml and 3) EVC-IVC (L) > 200 ml. 100 ml, as proposed by Mottram[7], were established for the minimum limit of differences.

For the characterization of the sample, we used descriptive statistical methodologies. In the case of quantitative variables, we used measures of central tendency (sample mean) and measures of dispersion (deviation-pattern). Regarding the qualitative variables, we used frequency distribution. We used the Kolmogorov-Smirnov Test to check if the distribution of variables was a normal distribution. If the variables under consideration followed this type of distribution, parametric statistical methods were applied. We used the One-Way Anova Test with Post Hoc Multiple Comparisons through the Tukey Test for the purpose of understanding if lung function variables were significantly different among the three defined ventilatory groups. In the airway obstruction and restrictive lung disease groups we evaluated possible differences in the variables EVC (L and %), IVC (L and %) and EVC-IVC (L and %) relating to the degrees of severity of ventilatory defects. We used the One-Way Anova with Post Hoc Multiple Comparisons through the Hochberg's GT2 Test. In order to study the connections between the EVC-IVC parameter (L and %) and the FEV_1%, TLC%, FRC% and RV% variables, we made the Pearson Correlation Test. For every statistical test, the significance level was 0.05.

Results

The sample consisted of 388 individuals; 209 male (53.9%) and 179 female (46.1%). It was confirmed that 42.3% of the subjects had a normal ventilatory pattern; 38.1% had airway obstruction and 19.6% had restrictive lung disease. We observed that most patients of the airway obstruction and restrictive lung disease groups showed mild ventilatory defect (52.7% and 52.6%) (**Table 1**).

TABLE 1. Demographic. Anthropometric and Ventilatory Pattern Characteristics of the Overall Sample

Demographic and anthropometric characterization		Characterization of the ventilatory pattern		
Sex n (%)	M - 209 (53.9) F - 179 (46.1)	Normal n (%)	Airway obstruction n (%)	Restrictive lung disease n (%)
Age (years)	56.3 ± 14.1	164 (42.3)	148 (38.1)	76 (19.6)
Height (m)	1.64 ± 0.09		Degree of severity n (%	
Weight (Kg)	74.4 ± 16.2		Mild - 78 (52.7) Moderate - 30 (20.3) Moderately severe - 18 (12.2) Severe - 16 (10.8) Very severe - 6 (4.0)	Mild - 40 (52.6) Moderate - 25 (32.9) Moderately severe - 11 (14.5)
BMI (Kg/m^2)	27.5 ± 5.34			

Data shown: mean ± deviation-pattern; number of individuals (n) and percentage (%)
F - female ; BMI – Body Mass Index ; M - male

Through the analysis of lung function variables obtained from the three established groups, we verified the existence of statistically significant differences ($p < 0.05$) in the mean values of the EVC-IVC (L and %) and FEV_1 (L) parameters between the normal vs. airway obstruction and normal vs. restrictive lung disease groups. The mean values of the FEV_1/FVC, FEV_1/EVC and FEV_1/IVC ratios were statistically different ($p < 0.05$) in the three groups. The mean value for the EVC was higher than the mean IVC in all the lung function groups. The highest mean value for EVC-IVC -170 mL and 5% - was confirmed in the normal ventilatory pattern group (**Table 2**).

In the group with a normal ventilatory pattern, the difference between the EVC and IVC (L) was < 100 ml in 32.3% of the individuals; between 100 ml and 200 ml in 32.9%, and > 200 ml in 34.8%. In the group with airway obstruction, those differences were 37.2%, 34.4% and 28.4%. And in the group with restrictive lung disease, the differences were 56.6%, 21.0% and 22.4% (**Table 3**).In the group with airway obstruction, we confirmed that the mean value for the EVC (L), IVC (L) and EVC-IVC (%) parameters had a statistically significant difference ($p < 0.05$) between the mild vs. severe and mild vs. very severe groups. The mean value for the EVC-IVC (L) parameter in the group with mild airway obstruction was significantly different ($p < 0.05$) from that verified in the group with very severe obstruction. The EVC mean values (%) were statistically different ($p< 0.05$) in all the groups with different airway obstruction degrees of severity. In the group with restrictive lung disease, the mean values for the EVC (%) and IVC (%) variables were significantly different ($p < 0.05$) in the three degrees of severity for ventilatory defects. With regard to the remaining parameters, no statistically valuable differences have been confirmed ($p > 0.05$). In the group with airway obstruction, the mean values for the EVC (L and %) were proven to be higher than the IVC (L and %) in the mild and moderate degrees; however, in the severe and very severe degrees, the IVC mean value (L and %) was higher than the EVC (L and %) (**Table 4**).

The FEV_1/EVC ratio of < 0.70 identified the presence of airway obstruction in 44.8% of the overall sample, and the FEV_1/IVC ratio of < 0.70 in 39.4% (**Figure 1A**). In the group of individuals with airway obstruction, the whole-body plethysmography performed with the EVC maneuver determined the presence of air trapping in 21.6% of the elements and lung hyperinflation in 9.5%, whereas the IVC maneuver determined the existence of air trapping in 18.2% of the elements and lung hyperinflation in 10.8% (**Figure 1B**). In the restrictive lung disease group, the TLC_{EVC} analysis classified the restrictive lung disease as mild in 54.0% of the individuals, moderate in 34.2% and moderately severe in 11.8%. The TLC_{IVC} analysis classified the disease as mild in 47.4% of the subjects, moderate in 36.8% and moderately severe in 15.8% (**Figure 1C**).

Taking into account the overall sample, we verified the existence of a weak positive correlation ($r=0.355$; $p=0.000$) between the FEV1 (%) and EVC-IVC (L) parameters, and a moderate positive correlation ($r=0.402$; $p=0.000$) between the FEV1 (%) and EVC-IVC (%). Weak negative correlations have been obtained between the FRC (%) and EVC-IVC (L) and EVC-IVC (%) parameters ($r=-0.117$;

TABLE 2. Lung Function Characterization According to the Ventilatory Pattern

	Normal (n = 164)	Airway obstruction (n = 148)	Restrictive Lung Disease (n = 76)
FVC (L)	2.76 ± 0.74*#	1.90 ± 0.76*	2.03 ± 0.55#
FVC (%)	101.1 ± 13.7§	69.7 ± 19.1§	75.4 ± 13.0§
EVC (L)	3.53 ± 0.89§	3.24 ± 1.05§	2.51 ± 0.67§
EVC (%)	107.6 ± 14.6§	96.0 ± 17.1§	76.7 ± 11.8§
IVC (L)	3.61 ± 0.94§	3.33 ± 1.08§	2.63 ± 0.71§
IVC (%)	106.5 ± 14.7§	95.4 ± 17.4§	76.5 ± 11.4§
EVC-IVC (L)	3.47 ± 0.88#	3.28 ± 0.95# ǂ	2.55 ± 0.66#
EVC-IVC (%)	102.4 ± 13.4§	94.4 ± 15.4§	74.4 ± 10.8§
FEV_1/FVC	0.17 ± 0.12*	0.05 ± 0.24 *	0.08 ± 0.14# ǂ
FEV_1/EVC	5.09 ± 4.69*#	0.99 ± 6.16*#	2.13 ± 3.94# ǂ
FEV_1/IVC	0.78 ± 0.05*	0.57 ± 0.10*#	0.80 ± 0.05# ǂ
TLC_{EVC} (L)	0.76 ± 0.06*	0.56 ± 0.10*#	0.77 ± 0.07# ǂ
TLC_{EVC} (%)	0.79 ± 0.07*	0.57 ± 0.11*#ǂ	0.79 ± 0.08# ǂ
TLC_{IVC} (L)	5.24 ± 1.02§	5.94 ± 1.20§	3.88 ± 0.78§
TLC_{IVC} (%)	96.9 ± 9.89§	102.9 ± 13.3§	69.3 ± 8.22§
FRC_{EVC} (L)	5.18 ± 1.02§	5.87 ± 1.15§	3.82 ± 0.76§
FRC_{EVC} (%)	95.8 ± 9.88§	101.9 ± 13.7§	68.1 ± 8.53§
FRC_{IVC} (L)	2.63 ± 0.64§	3.50 ± 0.92§	1.97 ± 0.53§
FRC_{IVC} (%)	89.6 ± 16.8§	111.8 ± 25.3§	64.4 ± 13.5§
RV_{EVC} (L)	2.66 ± 0.64§	3.49 ± 0.88§	1.95 ± 0.52§
RV_{EVC} (%)	90.8 ± 17.3§	111.3 ± 25.3§	63.8 ± 13.6§
RV_{IVC} (L)	1.64 ± 0.48§	2.61 ± 0.79§	1.26 ± 0.44§
RV_{IVC} (%)	86.2 ± 19.6§	123.0 ± 38.5§	62.3 ± 16.8§
RV_{IVC}(L)	1.72 ± 0.45§	2.59 ± 0.73§	1.28 ± 0.42§
RV_{IVC}(%)	90.7 ± 18.1§	122.7 ± 35.2§	63.7 ± 16.6§

Data shown: mean ± deviation-pattern
Comparison of mean values for the three groups: One-way Anova + Post Hoc Multiple Comparisons (Tukey Test
◊ Statistically significant differences between the normal group and the airway obstruction group
Statistically significant differences between the normal group and the restrictive lung disease groupr
* Statistically significant differences between the airway obstruction group and the restrictive lung disease group
• Statistically significant differences in the three groups
Results with 0.05 significance leve
EVC - expiratory vital capacity; FEV_1 - maximum expiratory volume in first second of forced expiration; FRC - functional residual capacity; FVC - forced vital capacity; IVC - inspiratory vital capacity; TLC - total lung capacity; RV - residual volume

p=0.021 and r=-0.152; p=0.003, respectively) and between the RV (%) parameter and EVC-IVC (L) and EVC-IVC (%) (r=-0.311; p=0.000 and r=-0.334; p=0.000 respectively) (Figure 2).

DISCUSSION

The determination of the VC may contribute to differences in the volumes obtained, due to its inherent characteristics. This research confirmed that the use of the EVC or IVC generates different VC volumes

TABLE 3. Characterization of volume differences between the EVC and IVC according to the ventilatory pattern

EVC-IVC (L) ≤ 100 ml n (%)	53 (32.3)	55 (37.2)	43 (56.6)
100 ml < EVC-IVC (L) ≤ 200 ml n (%)	54 (32.9)	51 (34.4)	16 (21.0)
EVC-IVC (L) > 200 ml n (%)	57 (34.8)	42 (28.4)	17 (22.4)

Data shown: number of individuals (n) and percentage (%)
EVC - expiratory vital capacity; IVC - inspiratory vital capacity

TABLE 4. Lung function characterization according to the degree of severity of the airway obstruction and the restrictive lung disease

	Airway obstruction (n = 148)					Restrictive lung disease (n = 76)		
	Mild (n = 78)	Moderate (n = 30)	Moderately severe (n = 18)	Severe (n = 16)	Very severe (n = 6)	Mild (n = 40)	Moderate (n = 25)	Moderately severe (n = 11)
EVC (L)	3.72 ± 1.16*◊	3.13 ± 0.79	2.99 ± 0.72	2.52 ± 0.72*	2.21 ± 0.38◊	2.77 ± 0.77	2.46 ± 0.51	2.49 ± 0.83
EVC (%)	105. 0 ± 13.4•	94.3 ± 11.3•	81.5 ± 8.95•	76.2 ± 14.5•	60.3 ± 5.99•	81.6 ± 9.65•	74.4 ± 8.24•	62.5 ± 11.1•
IVC (L)	3.62 ± 1.02*◊	3.08 ± 0.71	2.99 ± 0.66	2.65 ± 0.65*	2.39 ± 0.39◊	2.70 ± 0.70	2.35 ± 0.48	2.46 ± 0.80
IVC (%)	102.7 ± 11.5•	93.4 ± 11.2•	82.2 ± 8.92•	77.6 ± 14.6•	63.2 ± 4.96•	79.8 ± 8.69•	71.2 ± 8.34•	61.6 ± 9.73•
EVC-IVC (L)	0.10 ± 0.23◊	0.04 ± 0.15	- 0.01 ± 0.29	- 0.04 ± 0.28	- 0.32 ± 0.07◊	0.07 ± 0.15	0.11 ± 0.12	0.032 ± 0.11
EVC-IVC (%)	2.32 ± 5.88*◊	0.97 ± 4.64	- 0.67 ± 7.10	- 1.38 ± 7.89*	-2.83 ± 1.94◊	1.80 ± 4.16	3.20 ± 3.93	0.91 ± 2.66

Data shown: mean ± deviation-pattern
Comparison of the mean values in the three groups: One-way Anova + Post Hoc Multiple Comparisons (Hochberg´s GT2 Test)
* Statistically significant differences between the mild airway obstruction group and the severe airway obstruction group
◊ Statistically significant differences between the mild airway obstruction group and the very severe airway obstruction group
• Statistically significant differences in all the groups
Results with 0.05 significance level
EVC - Expiratory vital capacity; IVC - inspiratory vital capacity

and consequent differences in lung volumes. We observed that the use of the EVC, IVC or parameters not including the VC classify patients differently regarding the lung function level. That is why the authors indicate that the EVC and the IVC should not be considered interchangeable maneuvers.

Few studies conducted several decades ago addressed this topic. Bencowitz[13] studied volume differences between the EVC and IVC in sixty individuals (with and without obstruction, jointly analyzed) and determined a mean difference of 79 ml. The author considered it a minor difference, and suggested that the VC is similar with both maneuvers. In a sample of six healthy individuals and six patients with lung emphysema, the differences obtained by Hutchinson[3] regarding the EVC and IVC were similar between the groups (healthy - 20 ml and emphysema - 60 ml). The analysis of the mean values didn't show valuable differences related to the EVC and IVC in any of the studies. On the contrary, this study verified that the differences between the EVC and the IVC are more evident, mostly in the group with a normal ventilatory pattern (170 ml). In the groups with airway obstruction and restrictive lung disease, those differences were 50 ml and 80 ml, respectively, being the EVC higher than the IVC. According to Lutfi[14], volume variations between the VC types of maneuvers are slight in individuals with a normal ventilatory pattern; however, that was not verified in this research, since it was in that group that the greatest volume differences between the EVC and IVC were observed.

The differences between the results found in the literature and those obtained in this study could be related to methodological characteristics, because the reported studies analyzed a reduced number of individuals and didn't group them according to their ventilatory pattern. Taking into account the results of this research, there are fewer differences in the group with airway obstruction compared

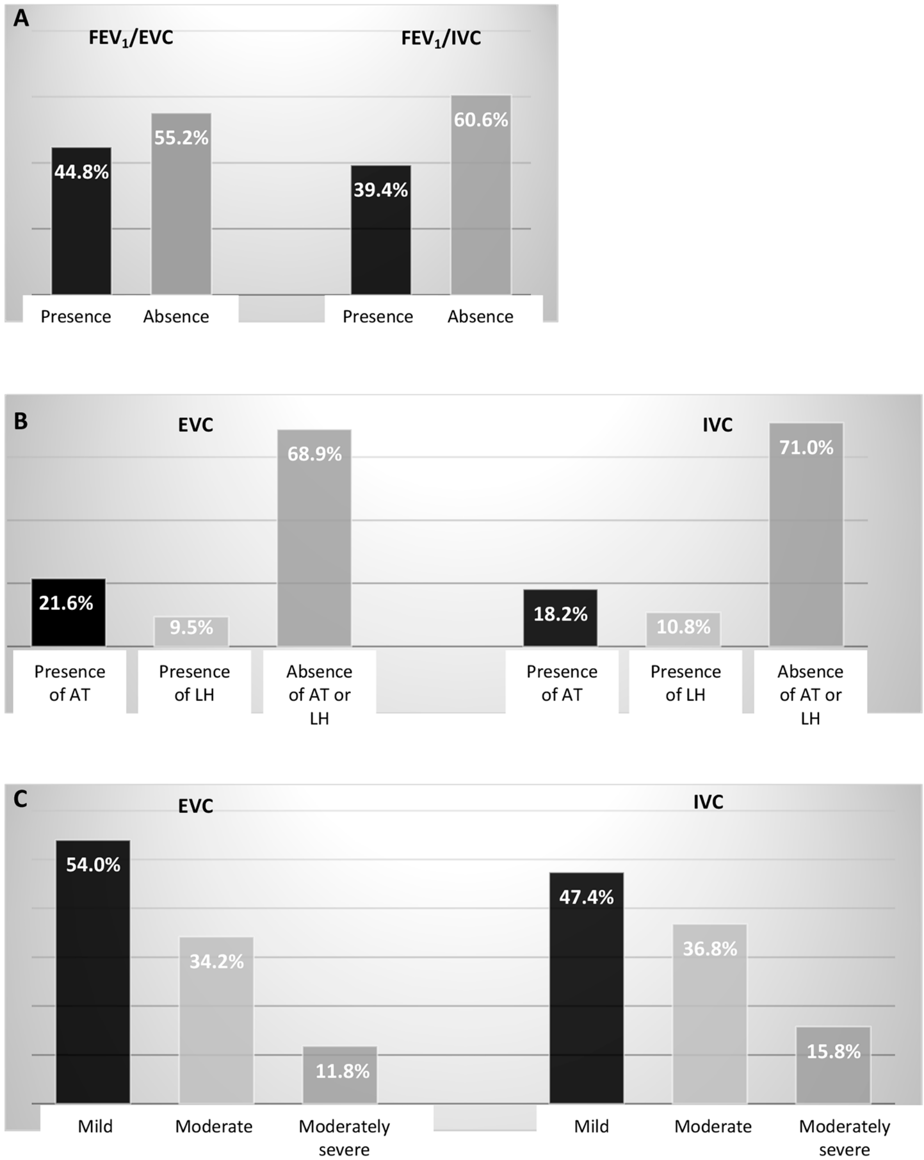

Figure 1. Sample characterization according to the presence of airway obstruction (FEV_1/EVC and FEV_1/IVC) - A; air trapping (AT) and lung hyperinflation (LH) - B; severity of restrictive lung disease - C; (EVC and IVC maneuvers)

to the differences found in the group of normal individuals; therefore, the joint analysis of the mean value shows lower EVC-IVC values.

Through the analysis of individuals with airway obstruction we confirmed a mean EVC higher than the mean IVC (3.33 L vs. 3.28 L; $p>0.05$). The results obtained by the EVC and IVC subanalysis according to the degrees of severity of the obstruction revealed that in the mild and moderate airway obstruction groups the mean EVC was higher than the mean IVC. However, in the groups with severe and very severe obstruction the results were inverted, and the mean IVC was higher than the mean EVC (there are more differences between the two VC maneuvers as the severity of the ventilatory defect increases). This particularity may be responsible for the similarity between the mean EVC and IVC in the analysis of the obstruction group as a whole. The results achieved by Brusasco et al.[4] in their

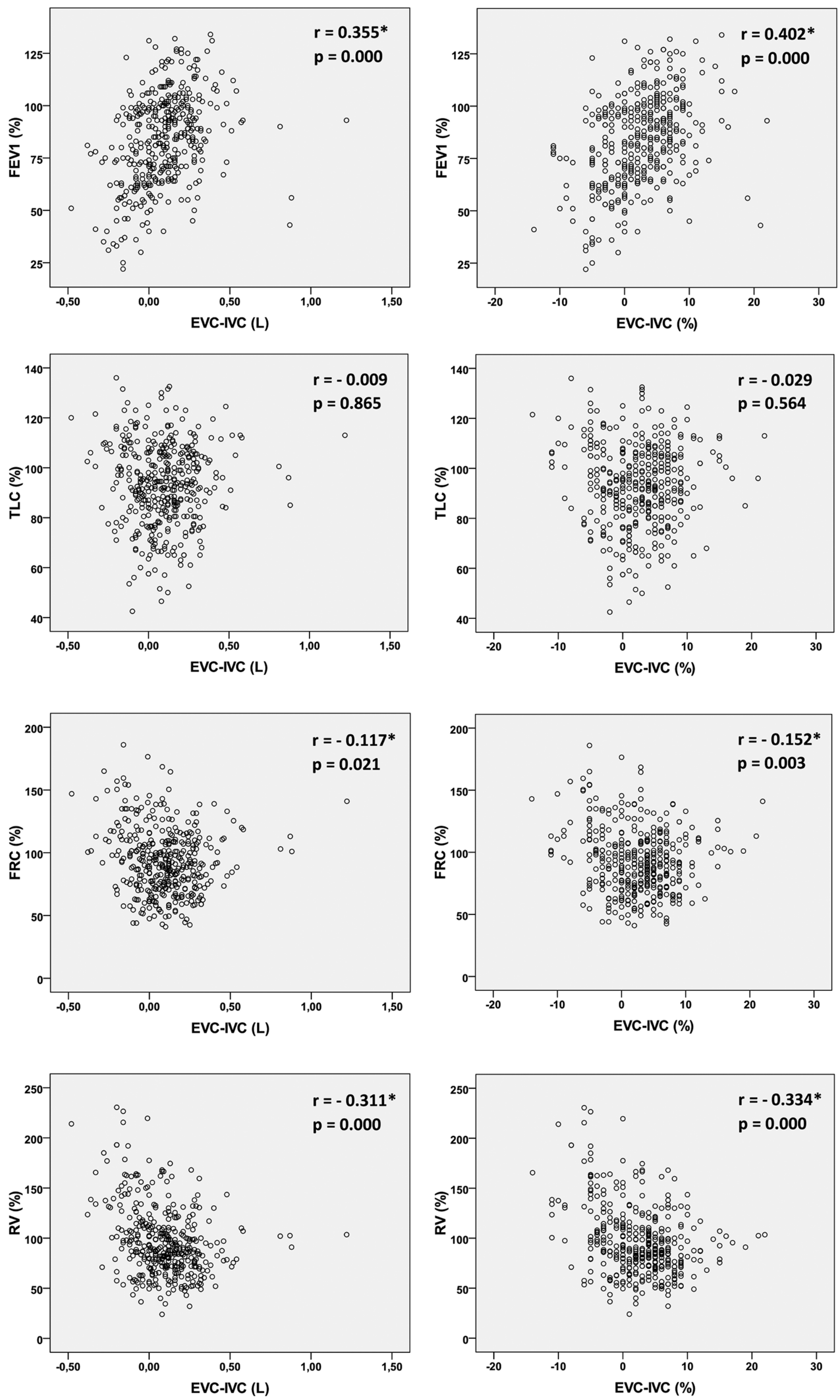

Figure 2. Pearson Correlation Coefficient between the FEV1%, TLC%, FRC%, RV% and EVC-IVC L and % parameters

research are similar to the results of this study: a sample of twenty five individuals with obstruction obtained a mean EVC-IVC of 110 ml, where the IVC is higher than the EVC (the author didn't divide the sample according to the severity of the obstruction). The results obtained in the group with airway obstruction agree with the literature; Sicar[5] and Barreto[6] report that in individuals with airway obstruction, the IVC is higher than the EVC. The resistance of the airways is stronger during expiration, compared to inspiration, because when the person expires progressively the lung is less relaxed and the elastic recoil decreases. The radial traction of the airways causes a decrease in their caliber, and the intrapleural pressure is higher during expiration, also reducing de airway caliber[14]. This particularity justifies the reason why in individuals with normal ventilatory pattern and mild and moderate airway obstruction the EVC is higher than the IVC; and in the most severe cases of obstruction, where a significant increase in airway resistance is expected, the IVC turns out to be higher than the EVC.

According to the acceptance criteria proposed by Mottram[7], the VC maneuvers should not differ in more than 100 ml. The results showed that, except for the group with restrictive lung disease, where 56.6% of the sample had an EVC-IVC of less than 100 ml, most individuals in the remaining groups had an EVC-IVC of more than 100 ml. Bencowitz[13] did not achieve a valuable mean value for the differences when he analyzed the differences between EVC and IVC individually, but he did verify that in 63.3% of the sample individuals that difference was positive and above 100 ml. This percentage was similar to that observed in the group with normal ventilatory pattern and airway obstruction (67.7% and 62.8%, respectively). These results alert us to the existence of volume differences higher than the limit expected for reproducibility between VC maneuvers (100 ml), which means that the EVC and the IVC are not equivalent maneuvers.

Since the VC determines the calculation of the RV and TLC, we analyzed the presence of air trapping or lung hyperinflation in the airway obstruction group, basing on the following variables: RV_{EVC} and RV_{IVC}, FRC_{EVC} and FRC_{IVC}, and TLC_{EVC} and TLC_{IVC}. We confirmed that the EVC maneuver detected a larger number of subjects with air trapping compared to the IVC maneuver (21.6% and 18.2%, respectively). The distribution of elements according to the categories (absence of air trapping or lung hyperinflation and presence of lung hyperinflation) was not similar, which means that the type of maneuver influences the characterization of lung volumes.

The same type of analysis was applied to the group with restrictive lung disease, taking into account the TLC_{EVC} and TLC_{IVC} parameters. The same trend was confirmed in the results because the distribution of individuals relative to the degrees of severity of restrictive lung disease has been different, according to the type of VC maneuver that was performed. One possible explanation for obtaining a higher amount of individuals with mild restrictive lung disease by TLC_{EVC}, compared to TLC_{IVC} could be the fact that it is easier for the individuals to move an ERV larger than the IRV.

This research evidenced the existence of statistically significant associations among the FEV_1%, FRC% and RV% with differences between the EVC and IVC (EVC-IVC). After analyzing these associations we could verify that there are more differences regarding the two types of maneuvers in individuals with higher FEV_1% and in individuals with lower FRC% and RV%. Even though the correlation coefficient values were of mild or moderate intensity, the fact that there is a statistical significance in three out of four ratios under evaluation makes these associations valuable for the authors. Bencowitz[13] also studied the ratios between the FEV_1 and RV/TLC and the differences between EVC and IVC, though the correlation coefficients obtained did not have statistical importance.

The Chhabra[15] study, which included sixty asthmatic subjects and twenty individuals without any respiratory disease, verified a FEV_1/IVC ratio lower than the FEV_1/EVC ratio in both groups. The author considered the differences between the EVC and the IVC as non-valuable, and didn't analyse the repercussions of using each ratio in the classification of individuals as obstructive or not obstructive.

In this research, the FEV_1/EVC ratio determined the presence of airway obstruction in 44.8% of the individuals, and the FEV_1/IVC ratio in 39.4%; this means that the EVC was a larger denominator than the IVC, allowing for a greater capacity to detect this ventilatory defect. Taking into account what was already mentioned in relation to the flow of larger volumes through the IVC in subjects with obstruction, we would expect the ratio with greater capacity to detect obstruction to be the FEV_1/IVC. The authors explain this result stating the fact that the EVC is higher than the IVC in mild and moderate obstruction of the airways, creating a FEV_1/EVC ratio lower than the FEV_1/IVC. As regards the groups with severe and very severe obstruction, a low FEV_1 is obtained, so the ratios are reduced as the numerator is reduced. So, both ratios detected the presence of airway obstruction with these degrees of severity.

Conclusions

The results obtained from this research show that the EVC and IVC should not be assumed to be identical maneuvers because volume differences are obtained in each of them, and they condition the interpretation of lung function tests. The EVC and IVC promote different results relating to the characterization of lung volumes (air trapping and lung hyperinflation) and also promote variations in the classification of the restrictive lung disease degrees of severity.

Considering the results obtained, we suggest the use of the EVC in individuals with restrictive lung disease, because the TLC_{EVC} allows for a safer classification of the ventilatory defect degree of severity.

The authors suggest the use of EVC in individuals with normal ventilatory pattern and mild and moderate airway obstruction. The expiratory maneuver revealed a larger airflow capacity, thus promoting a greater detection of airway obstruction. Taking into account the particularities of the respiratory system behaviour in cases of more severe airway obstruction, the IVC has larger airflow capacity under such circumstances, so, we suggest that the VC is determined using the IVC maneuver in these subjects.

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