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**OSCILOMETRIA DE IMPULSO PODE SER USADA PARA  
AVALIAR E DIFERENCIAR A RESISTÊNCIA E A ELASTÂNCIA DAS  
VIAS AÉREAS NOS IDOSOS FUMANTES DOS NÃO FUMANTES**

IMPULSE OSCILLOMETRY CAN BE USED TO EVALUATE AND DIFFERENTIATE  
AIRWAYS RESISTANCE AND ELASTANCE IN ELDERLY SMOKERS FROM NON-  
SMOKERS

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**OSCILOMETRIA DE IMPULSO PODE SER USADA PARA AVALIAR E  
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IMPULSE OSCILLOMETRY SYSTEM, RESPIRATORY AND PERIPHERAL  
STRENGTH IN FORMER SMOKERS AND CHRONIC OBSTRUCTIVE  
PULMONARY DISEASE INDIVIDUALS

Orientador: Prof. Dr. Rodolfo de Paula Vieira

Artigo apresentado ao Programa de Pós-Graduação em Bioengenharia da Universidade Brasil, como complementação de créditos necessários para a obtenção do título de Mestre em Bioengenharia.

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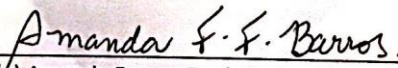
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**“OSCILOMETRIA DE IMPULSO PODE SER UTILIZADA PARA AVALIAR E DIFERENCIAR A RESISTÊNCIA E A ELASTÂNCIA DAS VIAS AÉREAS EM IDOSOS FUMANTES DE NÃO FUMANTES”**

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## 1. INTRODUÇÃO

O envelhecimento é um processo natural e fisiológico enfrentado pela população. É descrito por diversas teorias, uma delas, alerta para o declínio progressivo da homeostase celular, gerando doenças crônicas e aumento da taxa de mortalidade. <sup>(1)</sup>

O sistema pulmonar continua se desenvolvendo após o nascimento, até em média 12 anos de idade, alcança maturidade com 25 a 30 anos e após, começa a enfrentar o declínio progressivo da função pulmonar. <sup>(2)</sup>

Com o declínio da função pulmonar, ocorre alteração da estrutura pulmonar e da parede torácica, também acontece alteração dos músculos respiratórios. O recuo elástico pulmonar diminui com o envelhecimento, diminuindo a tensão superficial dos alvéolos. A conformidade da caixa torácica diminui progressivamente e a rigidez das costelas aumentam, gerando um aumento da resistência pulmonar. Em geral, a força muscular diafragmática diminui, afetando o padrão respiratório. <sup>(2,3)</sup>

Todas essas alterações fisiológicas e progressivas afetam o sistema respiratório de maneira difusa. A função do pulmão é prejudicada. Existe uma diminuição do volume expirado no primeiro segundo (VEF1), e da capacidade vital forçada (CVF), o volume residual (VR) aumenta, enquanto a capacidade vital (CV) diminui, em consequência da complacência torácica e recuo elástico diminuídos. <sup>(4,5)</sup>

O pulmão idoso tem maior propensão a doenças respiratórias, podendo ter o quadro agravado por substâncias nocivas ao sistema respiratório. <sup>(5)</sup>

O tabaco é responsável por mais de 50 doenças diferentes, principalmente cardiovasculares e respiratórias. Provoca forte preocupação nos países desenvolvidos, pois representa elevado crescimento de mortes por seu uso. <sup>(6,7,8)</sup>

Entende-se por tabagismo o consumo de qualquer derivado do tabaco, produtor ou não de fumaça. A Organização Mundial de Saúde (OMS) reconhece o tabagismo como uma doença crônica, epidêmica, tendo como vetor a poderosa indústria do tabaco. <sup>(9,10)</sup>

A agressão decorrente da fumaça do cigarro atua diretamente nos tecidos, provocando reações fisiopatológicas com ligação direcionada à absorção dos produtos da combustão sobre o metabolismo e os mediadores químicos do próprio organismo. <sup>(1,5)</sup>

As doenças relacionadas ao aparelho respiratório requerem medidas de promoção e de prevenção à saúde do idoso, decorrentes de avaliação, com a redução de complicações de doenças pulmonares e prevenção de infecções comuns, virais e bacterianas, impactando diretamente na qualidade de vida do grupo. A avaliação e a quantificação do grau de disfunção tornam-se propícia à saúde do idoso, favorecendo a manutenção ou reconquista da autonomia e de sua capacidade. <sup>(4)(5)</sup>

A utilização da espirometria estabelece nos idosos um ponto centralizado que contribui com a avaliação do nível de distúrbio ventilatório, verificando a sua normalidade ou a classificação do tipo de distúrbio, o que favorece para indicar o tratamento e a evolução da saúde e da qualidade de vida. <sup>(4)(5)</sup>

A espirometria é um exame diagnóstico que requer de alta compreensão e força para realização, podendo ter seus resultados prejudicados por execução inadequada da técnica. <sup>(11)</sup>

Recursos tecnológicos modernos são desenvolvidos para realizar a avaliação da função pulmonar e a IOS surge com grande utilidade e confiabilidade para avaliação e diagnóstico devido à facilidade de aplicação. Requer apenas uma pequena colaboração do indivíduo avaliado que seria manter o volume corrente respiratório. <sup>(12)</sup>



Comprobación - Rechazo por parte del colaborador

Gracias por tomarse el tiempo para informar a Archivos de Bronconeumología de que no es autor colaborador de "Impulse oscillometry system (IOS), respiratory and peripheral strength in former smokers and chronic obstructive pulmonary disease individuals" presentado por Rodolfo Paula Vieira.

## 2. ARTIGO

### **Impulse Oscilometry Can Be Used to Evaluate and Differentiate Airways Resistance and Elastance in Elderlies Smokers from Non-Smokers**

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## **Abstract**

**OBJECTIVES:** The respiratory system changes with age and understanding these changes may help detect and prevent respiratory dysfunctions in the elderly. In addition, although the influence of smoking on lung function is well known, its influence on lung function and mechanics of elderly are unknown. Impulse oscillometry (IOS) is a technique for measurements of lung mechanics, which can reflect more precisely airway resistance/obstruction and lung tissue elastance than spirometric measurements.

**METHODS:** The present study compared 30 elderly never smokers ( $70,96 \pm 6,61$ ) with 30 elderly current smokers ( $69,96 \pm 5,94$  years old and  $35,33 \pm 24,93$ /packs/year tobacco load), without asthma or any other pulmonary disease in terms of lung function and mechanics.

**RESULTS:** The following differences between elderly never smokers versus smokers for spirometric values were found (FVC  $p < 0.02$ ; FEV1  $p < 0.04$ ; FEV1/FVC  $p < 0.04$ ; PEF  $p < 0.01$ ; MEF25%  $p < 0.02$ ; MEF50%  $p < 0.02$ ; MEF75%  $p < 0.01$ , IVC  $p < 0.01$ ) and for oscillometric values (Z5Hz  $p < 0.03$ ; R5Hz 0.01; R20Hz  $p < 0.04$ ; X5Hz  $p < 0.02$ ), while RFres and R5Hz-R20Hz did not present differences ( $p > 0.05$ ).

**CONCLUSIONS:** Impulse oscillometry can detect small airway resistance/obstruction to better differentiate the functional pulmonary response between elderly never smokers from smokers.

**Key words:** lung function, lung mechanics, impulse oscillometry, aging, smoking, COPD.

## INTRODUCTION

The worldwide rise in the populational aging resulted in increases of chronic diseases prevalence (Kennedy et al., 2014). This general aging trend without health prevention programs focused in early diagnostic and interventions results in increased health related costs (Wang et al., 2018). These issues as well as the mortality are enhanced by smoking (Mons and Brenner 2017).

There was a huge increase in chronic obstructive pulmonary disease (COPD) rates (Brandsma et al., 2017). According to the Global Initiative for Chronic Obstructive Pulmonary Disease (GOLD COPD) COPD is defined as a common, preventable and treatable disease that is characterized by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveolar abnormalities usually caused by significant exposure to noxious particles or gases (GOLD COPD 2017). The progressive airflow limitation in COPD is commonly characterized by reduced relation of FVC/FEV1 ( $\leq 0.7$ ) post-bronchodilator during spirometric test (GOLD COPD 2017). Impulse oscilometry (IOS) is a variant of forced oscillation technique (FOT) that allows the evaluation of lung mechanics without any respiratory effort (Brashier and Salvi 2015).

Several studies have reported that IOS can better differentiate the lung response between asthmatics smokers versus nonsmokers (Contoli et al., 2016), but such evaluation never has been performed in elderlies. Considering the need of pulmonary alterations early detection in elder smokers, the present study tested the hypothesis that lung mechanics study by (IOS) could be a useful method to evaluate the impact of smoking in elderly's lung function decline.

## **METHODS**

### **Ethical considerations and study design**

All experimental proceedings used in the present study has been approved by institutional ethical committee under number 1.021.635, according to the national recommendations for clinical studies.

Elderlies were recruited from House of Elderlies in the municipality of São José dos Campos – SP, Brazil. In total, 30 healthy, never smokers' elderlies (12 men and 18 women;  $70,96 \pm 6,61$  years old) and 30 current smokers (7 men and 23 women;  $69,96 \pm 5,94$  years old). The inclusion criteria were men and women above 60 years old, did not presenting any respiratory disease, capable to perform the forced maneuver for spirometric test. Specifically for smokers, they should be current smokers, for at least 15 years, as a  $35,33 \pm 24,93$ /packs/year (tobacco load).

### **Evaluation of Lung Function by Spirometry**

Lung Function was evaluated by spirometry by Master screen PFT Oscilometry system (Jaeger, Germany), by using the forced maneuver, according to the ATS recommendations' (Culver et al., 2017). The evaluated parameters were forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), the ration between (FEV1/FVC), peak expiratory flow (PEF), maximal expiratory flow at 25% of FVC (MEF25%), maximal expiratory flow at 50% of FVC (MEF50%) and maximal expiratory flow at 75% of FVC (MEF75%).

## **Evaluation of Lung Mechanics by Impulse Oscillometry**

Lung mechanics was evaluated by impulse oscillometry by using the Masterscreen PFT Oscillometry system (Jaeger, Germany) (Schulz et al., 2013). The following parameters have been measured: R5Hz (total resistance of respiratory system), R20Hz (resistance of proximal airways), R5Hz-R20Hz (resistance of distal airways), X5Hz (reactance - elasticity of the lung tissue) and Z5Hz (impedance of the respiratory system) and Fres (frequency of resonance of the respiratory system). The results were expressed as percentage of predicted value.

## **Statistical Analysis**

The software GraphPad Prism 5.0 was used to perform the statistical analysis. The analysis of normality was performed by Shapiro Wilk test. The data were presented as mean  $\pm$  standard deviation. The unpaired t-test was used and the p value  $<0.05$  was considered significant.

## **RESULTS**

### **Patients characteristics**

Sixty elderly, being thirty current smokers (12 men and 18 women;  $69,96 \pm 5,94$  years old and  $35,33 \pm 24,93$ /packs/year tobacco load) and thirty non-smokers/never smokers (7 men and 23 women;  $70,96 \pm 6,61$  years old).

### **Spirometry study**

The Figure 1 present the spirometric results comparing elderly smokers versus non-smokers. Figure 1 A shows that FVC was significantly reduced in elderly smokers x non-smokers ( $p<0.002$ ). Figure 1 B shows that FEV1 was significantly

reduced in elderly smokers x non-smokers ( $p < 0.04$ ). Figure 1 C shows that FEV1/FVC was significantly reduced in elderly smokers x non-smokers ( $p < 0.04$ ). Figure 1 D shows that PEF was significantly reduced in elderly smokers x non-smokers ( $p < 0.01$ ). Figure 1 E and 1 F shows that MEF25% and MEF50%, respectively, was significantly reduced in elderly smokers x non-smokers ( $p < 0.02$ ). Figure 1 G and 1 H, shows that MEF75% and IVC, respectively, was significantly reduced in elderly smokers x non-smokers ( $p < 0.01$ ).

### **Oscilometric study**

The Figure 2 present the oscilometric results comparing elderly smokers versus non-smokers. Figure 2 A shows that Z5Hz was significantly reduced in elderly smokers x non-smokers ( $p < 0.03$ ). Figure 2 B shows that R5Hz was significantly reduced in elderly smokers x non-smokers ( $p < 0.01$ ). Figure 2 C shows that R20Hz was significantly reduced in elderly smokers x non-smokers ( $p < 0.04$ ). Figure 2 D shows that R5Hz-R20Hz did not present differences comparing elderly smokers x non-smokers ( $p > 0.05$ ). Figure 2 E shows that X5Hz was significantly increased in elderly smokers x non-smokers ( $p < 0.02$ ). Figure 2 F shows that Fres did not present differences comparing elderly smokers x non-smokers ( $p > 0.05$ ).

### **DISCUSSION**

The present study showed for the first time that elderlies' smokers present impaired lung function and mechanics compared with non-smokers, especially in distal airways. In addition, the present study also showed for the first time that IOS is

a sensible and useful tool to better differentiate the lung mechanics of elderlies, since no effort is needed, such as in spirometry.

The findings showing impaired lung function in elderlies smokers agree with previous studies demonstrating that in adults the smoking impairs the lung function (Katoh et al., 2001; Gupta et al., 2017). However, there is a high rate of non-smoking elderlies who did not present respiratory symptoms, but present increased obstruction and resistance of distal airways (Betsuyaku et al., 1996; Gupta et al., 2017; Schivinski et al., 2017). In some cases, passive smokers, independent of age, can present normal lung function, with impaired lung mechanics, reinforcing that lung mechanics assessment can predict early alterations of the airways (Betsuyaku et al., 1996; Gupta et al., 2017; Schivinski et al., 2017; García-Quero et al., 2019).

It is also known that elderlies' smokers present accelerated decline in the lung function (FVC, FEV1 and FEV1/FVC), compared with non-smokers (Katoh et al., 2001; Omori et al., 2005; Tantisuwat et al., 2014; Gupta et al., 2017). In the present study, we also observed impaired lung function in elderlies' smokers. However, the evaluation of lung mechanics by IOS displayed more detailed information, demonstrating increased elastance of proximal airways, as demonstrated by severe reduction in the proximal airway resistance (reduced R20Hz) and by a severe increase (2x fold) in the distal airway resistance (increased X5Hz). These results reinforce or reflect the strong reduction in MEF75%, which preferable demonstrates the obstruction of the small airways. It has been also reported that reduction in MEF75% reflects histological alterations of small airways (Cosio et al., 1977). Such findings reinforce the typical COPD characteristics, with increased resistance and air

flow limitation of small airways and decrease of the elastance of proximal airways (Capron et al., 2019). Of note, it has been established that small airways alterations precede emphysema development (Capron et al., 2019). In addition, the consequences of smoking specifically on small distal airways has been reported (Verbanck et al., 2006).

The X5Hz represent the lung elastic recoil forces, which is related to the inertial forces of the distal airways, of the lung tissue and thorax (Bickel et al., 2014). In this way, it is possible that elderlies' smokers present initial airway obstruction due to elastolysis of the elastic fibers in the distal airways (Kuperman et al., 1973; Cosio et al., 1977; Verbanck et al., 2006; Beasley et al., 2010; Bickel et al., 2014; Capron et al., 2019). In fact, the smoking habit induces the obstruction of small airways, beyond functional abnormalities and chronic obstructive pulmonary disease (Beasley et al., 2010). Therefore, the absence of proximal airway obstruction does not mean that smoking is not damaging the lungs (Verbanck et al., 2006). Furthermore, the consequences of smoking can be variable, in terms of affecting different regions of the lungs, depending of individual susceptibility (Verbanck et al., 2006; Capron et al., 2019).

The present study discusses a perspective of extreme clinical relevance, since IOS is a very simple, easy and effort independent pulmonary function test, really feasible to be performed by elderlies and children, who normally are unable to perform the spirometry maneuvers properly (Schulz et al., 2013; Bickel et al., 2014; Brashier et al., 2015). In fact, the present study detected a very good sensibility of IOS to detect fine differences between the lung mechanics of elderlies' smokers from



non-smokers. However, some points need to be clarified, as study' limitation: (i) the study involved elderly smokers with high tobacco load, (ii) the study did not randomized the volunteers among men and women, (iii) the study was performed only with 30 elderly in each group. Thus, further investigations should be done using a larger number of volunteers randomized by gender and also with different tobacco load.

## **CONCLUSION**

Impulse oscilometry systems (IOS) present enough sensibility to detect differences in airway resistance and elastance between elderlies' smokers from non-smokers, showing that smokers present reduced proximal airway resistance ( $R_{20\text{Hz}}$ ), below the normal level, indicating that elderlies' smokers present reduced airway elastance in comparison with elderlies' non-smokers. In addition, IOS was able to demonstrate by  $X_{5\text{Hz}}$  (reactance) that smokers present increased airway obstruction and resistance of distal airways, compared with non-smokers. In fact, IOS is useful tool to detect airway response in elderlies for being a method which is not effort dependent and is rapidly to be applied.

## **DISCLOSURE**

The authors report no conflicts of interest in this work.

## COMPETING FINANCIAL INTERESTS

All authors declare do not have any competing financial interests related to this publication.

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### **Figure Legends**

**Figure 1** – Lung function parameters, 1A (FVC), 1B (FEV1), 1C (FEV1/FVC), 1D (PEF), 1E (MEF25%), 1F (MEF50%), 1G (MEF75%) and 1H (IVC).

**Figure 2** – Lung mechanics parameters, 2A (Z5Hz), 2B (R5Hz), 2C (R20Hz), 2D (R5Hz-R20Hz), 2E (X5Hz), 2F (Fres).

### 3. CONSIDERAÇÕES FINAIS

O pulmão idoso associado aos efeitos deletérios do tabagismo, necessitam de tratamento adequado. Para que isso seja possível é necessário entender qual melhor meio de diagnóstico.

Sistemas de oscilometria de impulso (IOS) apresentam sensibilidade suficiente para detectar diferenças na resistência das vias aéreas e elastância entre fumantes e não fumantes, mostrando que os fumantes apresentam redução da resistência das vias aéreas proximais (R20Hz), abaixo do nível normal, indicando que os fumantes apresentam redução elastância das vias aéreas em comparação com os não fumantes de idosos.

Além disso, o IOS foi capaz de demonstrar por X5Hz (reatância) que os fumantes apresentam aumento da obstrução das vias aéreas e resistência das vias aéreas distais, em comparação com os não fumantes.

De fato, o IOS é uma ferramenta útil para detectar a resposta das vias aéreas em idosos por ser um método que não depende do esforço e está sendo aplicado rapidamente

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## 5. APÊNDICE

