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ORIGINAL ARTICLE

Preserved Ratio Impaired Spirometry (PRISm) in Individuals with Respiratory Symptoms Exposed to Wood Stoves

Preserved Ratio Impaired Spirometry (PRISm) em indivíduos com sintomas respiratórios expostos a fogões a lenha

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ABSTRACT

Objective: To investigate respiratory symptoms in patients who had never smoked but reported prolonged exposure time (ET) to wood-burning stove smoke. **Method:** Cross-sectional study carried out in a private practice from January 2019 to November 2021. Data on professional history, respiratory symptoms, and spirometry were collected. **Results:** A total of 101 patients were evaluated, 80 of whom were women and 53.47% were at least 60 years old. Eighteen patients (17.82%) were rural workers and 60.40% performed other occupational activities. Thirty-four (33%) patients reported exposure to wood-burning stove smoke for more than 40 years and 76 (75%) reported having two or more respiratory symptoms at the time of the medical examination, of which 51.49% reported cough, 59.41% reported dyspnea, 21.78% reported wheezing, and 20.79% reported chest pain. Approximately 64.36% were classified as PRISm and approximately 23.76% of the sample had an obstructive pattern in spirometry. No association was found between TE, symptoms and spirometric alterations. **Conclusion:** Patients exposed to wood stove smoke for a prolonged period, but who have never smoked, have a higher risk of respiratory symptoms, even if lung function is within normal limits. Most of our sample was classified as PRISm.

Keywords: Chronic obstructive pulmonary disease; Pulmonary function tests; Biomass; Smoke; Breathing.

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RESUMO

Objetivo: Investigar sintomas respiratórios em pacientes que nunca fumaram, mas relataram tempo de exposição (TE) prolongado à fumaça de fogão a lenha. **Método:** Estudo transversal realizado em consultório particular, de janeiro de 2019 a novembro de 2021. Foram coletados dados sobre histórico profissional, sintomas respiratórios e espirometria. **Resultados:** Foram avaliados 101 pacientes, sendo 80 mulheres em que 53,47% tinham pelo menos 60 anos. Dezoito pacientes (17,82%) eram trabalhadores rurais e 60,40% exerciam outras atividades ocupacionais. Trinta e quatro (33%) pacientes relataram exposição à fumaça de fogão a lenha há mais de 40 anos e 76 (75%) relataram ter dois ou mais sintomas respiratórios no momento do exame médico, dos quais 51,49% relataram tosse, 59,41% relataram dispneia, 21,78% relataram sibilância e 20,79% relataram dor torácica. Cerca de 64,36% foram classificados como PRISm e cerca de 23,76% da amostra apresentava padrão obstrutivo na espirometria. Não foi encontrada associação entre TE, sintomas e alterações espirométricas. **Conclusão:** Pacientes expostos à fumaça do fogão a lenha por um período prolongado, mas que nunca fumaram, apresentam maior risco de sintomas respiratórios, mesmo que a função pulmonar esteja dentro dos limites da normalidade. A maior parte da nossa amostra foi classificada como PRISm.

Palavras-chave: Doença pulmonar obstrutiva crônica; Testes de função pulmonar; Biomassa; Fumaça; Respiração.

Introduction

According to the World Health Organization (WHO), more than three billion people worldwide depend on solid fuels, such as firewood, coal, charcoal and organic waste, to meet their basic needs[1]. The use of wood-burning stoves could be responsible for more than 3 million deaths per year, including children. Diseases such as stroke, chronic obstructive pulmonary disease (COPD), cancer and heart disease are also common[2]. Wood-burning stoves are usually located indoors, in conditions of poor ventilation and poor exhaust[3]. Combustion in theses device occurs through a chemical process in which a material reacts rapidly with oxygen in the air, producing light and intense heat[4]. Respirable particles, produced by indoor or outdoor biomass combustion, are the most toxic pollutant in this context. The majority of it (94%) is made up of fine and ultrafine particles, that is, particles that penetrate deep into the respiratory tract, cross the epithelial barrier, reach the pulmonary interstitium and trigger inflammatory reactions[4,5].

Thus, acute inhalation of biofuel smoke can cause bronchial irritation, inflammation and bronchial reactivity, while prolonged exposure can lead to chronic airway inflammation. This can also increase susceptibility to bacterial and viral infections of the upper or lower respiratory tract[6]. Besides, smoking and exposure to wood smoke are considered significant risk factors for the development of respiratory diseases, especially COPD[7]. From an epidemiological point of view, estimating the prevalence of respiratory symptoms in a population helps to establish an indirect indicator of acute and chronic respiratory diseases with a high degree of reliability[8]. Self-reporting is a simple and direct way to obtain health information and presents a good level of consistency, reproducibility and cost-effectiveness compared to the results of clinical evaluation[8].

However, there are few studies investigating the influence of this risk factor on the development of respiratory symptoms. Therefore, this study aimed to investigate respiratory symptoms in patients who had never smoked but had been exposed to wood-burning stove smoke for a prolonged period.

Methods

This is an observational, cross-sectional study with a convenience sample. The study was conducted in a private outpatient clinic in the city of Diamantina, Minas Gerais, Brazil. The study included patients exposed to wood-burning stove smoke for at least 10 years, with no history of smoking, and who had completed the Informed Consent Form (ICF). This study was approved by the Research Ethics Committee (CEP) of Universidade Federal dos Vales do Jequitinhonha e Mucuri under number 4,048,776 and was guided by the Resolution of the National Health Council No. 466, of December 12, 2012, and by the Declaration of Helsinki. There was no financial incentive from any supporting source, and this study was carried out with the company's own resources.

The patient had to present at least one respiratory symptom (dyspnea, chronic cough, chest pain, wheezing) and must have been exposed to wood smoke for at least 10 years. This criterion for exposure to wood smoke was based on previous studies[9]. To assess the duration and intensity of exposure and reduce the possibility of recall error, we tried to use as reference facts from the participants' lives that could be easily remembered, such as the year they moved to a city or the year they got married.

As exclusion criteria, clinical evaluation was used that suggested bronchial asthma and/or allergic rhinitis and the existence of lung diseases and/or diseases with pulmonary repercussions capable of interfering with lung function, such as tuberculosis, pneumoconiosis, cystic fibrosis, bronchiolitis and alpha-1 antitrypsin deficiency.

Procedures

Data collection was performed by a single investigator through medical record review regarding assessment of respiratory symptoms and lung function. The study was conducted from January 2019 to November 2021 in a private practice by a pulmonologist. Participant assessment and data collection were performed on a single visit. However, all patients remained under medical supervision.

Data collected

Information on respiratory symptoms (dyspnea, chronic cough, chest pain, wheezing), time of continuous exposure to wood-burning stove smoke (in years), physical activity (self-reported), positive family history of lung disease (COPD, tuberculosis, asthma, lung cancer), occupation/employment, and anthropometric data such as sex, age, height, and weight were collected from medical records. The modified Medical Research Council (mMRC) dyspnea scale was used to assess dyspnea[10]. Regarding cough, patients who presented this symptom for more than eight weeks were classified as having chronic cough, according to the classification of the II Brazilian Guidelines for the Treatment of Chronic Cough[11]. Regarding physical activity, patients responded in a binary manner whether or not they exercised regularly. Body mass index (BMI) was calculated using the formula: BMI = body mass/height^2, and values between 18.5-24.9 kg/m^2 were considered normal. In spirometry, the following values were measured: forced vital capacity (FVC), forced expiratory volume in one second (FEV1). Pulse oximetry was used to measure peripheral oxygen saturation (SpO2) at rest.

Spirometry

Spirometry was performed and interpreted by a duly qualified health professional and in accordance with the guidelines of the Brazilian Society of Pulmonology and Tisiology (SBPT)[12] and the American Thoracic Society (ATS)[13]. The device used was the KOKO SX, version 5.0, year of manufacture: 2014, n-Spire Health Inc. It was calibrated daily and recalibrated when requested by the device software. To perform the bronchodilator test, 400 µg of salbutamol was administered to the patient through a nebulizer coupled to an air chamber. Pereira values[14] were used as predicted values. Spirometry was performed in all patients before and after bronchodilator administration.

In the interpretation of spirometry, obstructive lung disease (OLD) was assumed in the presence of FEV1/FVC and reduced FEV. The presence of Restrictive Ventilatory Disorder (RVD) was observed with a reduction in FVC in the absence of airway obstruction (preserved FEV1/FVC ratio)[12]. In addition, mixed lung disease (with evidence of obstructive and restrictive abnormality) and PRISm were considered present if the spirometry result showed an alteration but the FEV1/FVC ratio was preserved[15]. According to the Global Initiative for Obstructive Lung Disease (GOLD), PRISm can be defined as a spirometric pattern characterized by FEV1/FVC $\geq$0.70 and post-bronchodilator FEV1 < 80% of predicted[12].

Statistical analysis

For descriptive data analysis, continuous variables were presented as mean ± standard deviation, while categorical variables were presented as absolute and relative frequencies. Pearson's chi-square test and Fisher's exact test were used to compare the groups to compare exposure time, symptoms and respiratory disorders. Values of $p<0.05$ were considered significant. Data analysis was performed using IBM SPSS Statistics software, version 20.0 (IBM Corporation, Armonk, NY, USA).

Results

A total of 101 subjects took part in the study, most of whom were female (79.21%). The mean age was 62 ± 15 years, with the oldest individual being 87 years old and the youngest 20 years old. Furthermore, the majority (35.64%) of the population was obese, as shown in Table 1.

Overall, 17.82% of the respondents worked in agriculture and 60.40% were engaged in other professions. When asked about the family history of pulmonary comorbidities such as COPD, tuberculosis, asthma and lung neoplasia, 59.41% responded positively. Most of the patients did not practice regular physical activity (57.43%). Thirty-four patients (33.66%) had been exposed to wood stove smoke for more than 40 years.

At least one symptom was present in 75.24% of patients at the time of the study, and 52 patients reported two or more associated symptoms. Of those classified as symptomatic,

Table 1. Characteristics of the studied population.

Variables	Frequency n (%)
Sex	
Masculine	21 (20.79)
Feminine	80 (79.21)
Age group	
20 – 29 years old	4 (3.96)
30 – 39 years old	2 (1.98)
40 – 49 years old	21 (20.79)
50 – 59 years old	
> 60 years	20 (19.80)
54 (53.47)	
Body Mass Index (kg/m2)	
Normal (18.5-24.9 kg/m2)	25 (24.75)
Overweight (25 – 29.9 kg/m 2)	35 (34.65)
Obesity (30 – 39.9 kg/m 2)	36 (35.64)
Severe obesity (>40kg/ m2)	5 (4.95)

51.49% reported chronic cough, while 59.41% complained of dyspnea. Wheezing and chest pain occurred each in less than a quarter of patients, representing 20.79% and 21.78% of the sample, respectively. The most common type of respiratory disorder was Obstructive (23.76%) (Table 2). However, the majority presented PRISm (64.36%).

The association between prolonged exposure to wood stoves and the presence of respiratory symptoms was not observed in this study, as shown in Table 3.

Regarding the time of exposure to smoke from wood stoves, there was no association with the occurrence of respiratory diseases, as described in Table 4.

Discussion

The present study investigated the presence of respiratory signs and symptoms in individuals exposed to wood stove smoke for more than 10 years. The main conclusions are: (1) 75% of the population presents respiratory symptoms; (2) dyspnea was the most common symptom; (3) the lack of association between TE and the presence of signs and symptoms and spirometric alterations; and (4) the majority of the population was classified as PRISm.

Of the 101 patients studied, 75.24% presented respiratory symptoms, of which cough and dyspnea were the most common. They were on average older, 62 ± 15 years — the oldest person was 87 years old —, and the majority were female. It was expected that predominantly female patients would be exposed to smoke from wood stoves, since domestic exposure occurs mainly during cooking, a traditionally female activity. They were also less affected by the Brazilian rural exodus, which was intense and gradual

Table 2. Outcomes of the study population.

Occupation/professional	n (%)
Rural worker	18 (17.82)
Domestic	22 (21.78)
Other activity	61 (60.40)
Family History (COPD, Tuberculosis, Asthma, Lung Neoplasia)	
Absent	41 (40.59)
Present	60 (59.41)
Physical Activity	
No	58 (57.43)
Yes	43 (42.57)
Ventilatory Disorder	
PRISm	65 (64.36)
Obstructive	24 (23.76)
Restrictive	11 (10.89)
Mixed	1 (0.99)
Any symptoms	
Absent	25 (24.75)
Present	76 (75.25)
MRC	
Asymptomatic	25 (24.75)
1	24 (23.76)
2	33 (32.67)
>3	19 (18.81)
Chronic cough	
Absent	49 (48.51)
Present	52 (51.49)
Dyspnea	
Absent	41 (40.59)
Present	60 (59.41)
Ping	
Absent	80 (79.21)
Present	21 (20.79)
Chest pain	
Absent	79 (78.22)
Present	22 (21.78)
Smoke exposure time	
10 – 19 years old	31 (30.69)
20 – 29 years old	23 (22.77)
30 – 39 years old	13 (12.87)
> 40 years	34 (33.66)

Legend: COPD: chronic obstructive pulmonary disease; PRISm: Preserved Ratio Spirometry; MRC: Modified Medical Research Council.

Table 3. Distribution of respiratory symptoms according to time of exposure to smoke.

Wood smoke exposure time	*Respiratory symptoms*	
	Absent n (%)	Present n (%)
10 – 19 years old	9 (36)	22 (29)
20 – 29 years old	3 (12)	20 (26)
30 – 39 years old	3 (12)	10 (13)
> 40 years	10 (40)	24 (32)
Total	25 (100)	76 (100)

$(X^2) = 2.4137$; $p=0.491$.

Table 4. Distribution of the presence of respiratory diseases according to the time of exposure to smoke from wood stoves.

Wood smoke exposure time	Ventilatory Disorders	
	Absent n (%)	Present n (%)
10 – 19 years old	20 (31)	11 (31)
20 – 29 years old	13 (20)	10 (28)
30 – 39 years old	9 (14)	4 (11)
> 40 years	23 (35)	11 (30)
Total	65 (100)	36 (100)

$(X^2) = 0.9109$; $p=0.823$.

over the last four decades, having remained longer in rural areas[16].

Dyspnea was the most common symptom in the population of this study and, therefore, should be evaluated, but its high subjectivity should be considered. Cough was reported by 48.51% of patients, which leads us to consider the possibility of bronchitis, without lung function compatible with COPD. 20.79% of patients complained of wheezing and 21.78% of chest pain, observed only in a small proportion of the population. This finding may be due to the fact that this is the clinical expression that occurs mainly in the exacerbation of asthma and COPD, as it is an acute event characterized by worsening of respiratory symptoms in relation to the normal state[17]. However, we can highlight clinical relevance in this study.

Based on our results, if the diagnosis is COPD or asthma, these were based solely on respiratory symptoms, and the number of cases was probably overestimated. As demonstrated, the frequency of spirometric alterations was found in 35.6% of the sample, with an obstructive pattern predominating. The predominance of the obstructive pattern in spirometry observed in this study has been previously described in another study[15]. Compared with tobacco-related COPD, the alterations as a result of exposure to smoke from biomass burning are less pronounced. This is a contrast to the reports of severe COPD associated with the use of biomass in countries that, unlike Brazil, use animal manure and crop residues not only for cooking but also for heating their surroundings[18].

This study found no association between spirometric changes and prolonged exposure to wood-burning stove smoke, possibly due to individual factors. A study conducted in the northern region of Brazil[19] quantified the amount of soot ("black carbon") and particulate matter (PM2.5) in homes that used wood-burning stoves and showed an association between the intensity of pollution and the incidence of individuals with chronic respiratory symptoms and changes in lung function. The prevalence of respiratory symptoms in the group studied was 75.24%, similar to the present study.

One of the oldest models of wood-burning stoves is the three-stone stove. It is the most rudimentary and practical model, but it has very low energy efficiency and high smoke emissions. Another very common model is the model made of masonry, cement, clay and metal plates with holes for two or three pots; it does not have a stove or chimney. Because it does not have a chimney, this model, besides being a low energy source, also emits large amounts of smoke and particulate matter into the environment. These data once again show that the use of wood-burning stoves for cooking is the largest source of domestic pollution, with wood producing higher average concentrations of PM10 than coal[20].

Furthermore, in this study, we found that more than 60% of the population included did not have respiratory disease confirmed by spirometry, although they were exposed to wood stove smoke and had respiratory symptoms. This PRISm population has been studied in the last decade and occurs in 7% to 12% of the general population[15]. PRISm is associated with smoke exposure, increased respiratory symptoms and high body mass index in smokers without established lung disease[21,22]. This fact confirms our findings, since the entire population that was exposed to smoke presented at least one respiratory symptom and approximately 70% of the population was classified as overweight or obese.

Additionally, more than 50% of the population in this study presented symptoms of shortness of breath. This symptom is frequently associated with obesity[23], which confirms our results, since over 30% of the patients were obese. Obesity can favor the accumulation of fat in the mediastinum and abdominal cavities, which significantly alters the mechanical properties of the lungs and chest wall and contributes to changes in the normal physiology and function of the lungs[23]. However, we found that another factor related to the symptom of shortness of breath and obesity is a sedentary lifestyle[24], present in more than 50% of the patients. To avoid dyspnea on exertion, many patients adopt a sedentary lifestyle, which, predictably, leads to extensive skeletal muscle deconditioning a social isolation and its negative psychological consequences[24,25].

The limitations of this study include: the small number of participants; the fact that data were collected from medical records designed to assess and support diagnoses and occupational behaviors, rather than to systematic scientific research; data collection was performed by only one data collector; although the assessment forms contain questions about occupational exposure, these are not detailed or quantified, and it is not possible to establish an association between them and the presence of lung disease. Other possible limitations include the lack of objective measurement of the pollution level in a sample of households and the lack of advanced measures of lung function, such as plethysmography, measurement of carbon monoxide uptake and diffusion or transfer, cardiopulmonary exercise, among others. Furthermore, no radiological examinations were performed on the participants, and aspects related to the practice of physical activity, such as frequency and duration, were not recorded in detail. On the other hand, this study has the potential to serve as a basis for planning health interventions aimed at minimizing the adverse health effects associated with prolonged exposure to smoke from wood stoves. An effective mechanism for social empowerment is health education interventions that could be developed to promote public awareness of the need to switch from toxic to non-toxic energy sources. Those who cannot do without it in any situation should be advised on its appropriate use. The use of more energy-efficient firewood and the installation of a chimney to reduce the effects of smoke on respiratory health. However, it is known that this is difficult to follow in some households due to social vulnerabilities. Therefore, studies like this can also serve as a basis for planning, implementing and scaling up government reimbursement strategies such as "Gás dos Brasileiros"[26]. Finally, based on the results of this study, medical professionals are warned to avoid overtreatment of lung diseases based on the association between exposure to smoke from wood stoves and the occurrence of respiratory signs and symptoms. There is a need for more studies in the future that consider the assessment of more parameters of lung function; the evaluation of data on other environmental exposures (passive smoking and type of cigarette, agricultural work, location and characteristics of the stove) that will allow a better assessment of the role of wood smoke in the development of respiratory diseases. According to the present study, patients exposed to wood stove smoke for a long period of time, but who have never smoked, have a higher risk of respiratory symptoms, even if their lung function is within normal limits. This result demonstrated the need to change household energy sources, from toxic biofuels to cleaner and non-toxic fuels, such as electricity or gas. Moreover, this study established the importance of identifying individuals at increased risk of developing COPD and intervening accordingly. Except for those with early-stage disease who are at risk of progression, which may have important clinical implications. Therefore, studies are needed to evaluate other parameters of lung function and evaluate data on other environmental exposures (passive smoking and type of cigarette, agricultural work, location and characteristics of the stove). We also recommend new intervention studies, such as randomized clinical trials, to be conducted in individuals classified as prismatic to optimize and determine which treatments are most effective for this population, as PRISm has already been shown to be associated with an increased risk of mortality[27] and worsening of lung function[28] and that the progression of PRISm is closer to individuals with COPD than in those with normal spirometry[29].

Conclusion

According to the present study, patients exposed to smoke from wood stoves for a long time, without a history of previous smoking, have a higher risk of respiratory symptoms, despite having normal lung function. Most of our sample was classified as PRISm.

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Author's Contributions

We describe contributions to the papers using the taxanomy (CRediT) provide above:

Contributed to the design and construction of the study: JMA, PHSF, HSC, *and* VPL; *Performed data collection: JMA and* VPL; *Performed statistical analyses and data interpretation: PHSF, HSC, and VPL; Drafted the manuscript:* JMA *and* VPL; *Checked the final manuscript and critically revised it:* JMA, DMX, PHSF, HSC, *and* VPL. *All authors read and approved of the final manuscript.*

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