



Review

Pathogenic Mechanisms in Chronic Obstructive Pulmonary Disease Due to Biomass Smoke Exposure[☆]



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ABSTRACT

Chronic obstructive pulmonary disease (COPD) mortality and morbidity have increased significantly worldwide in recent decades. Although cigarette smoke is still considered the main risk factor for the development of the disease, estimates suggest that between 25% and 33% of COPD patients are non-smokers. Among the factors that may increase the risk of developing COPD, biomass smoke has been proposed as one of the most important, affecting especially women and children in developing countries.

Despite the epidemiological evidence linking exposure to biomass smoke with adverse health effects, the specific cellular and molecular mechanisms by which this pollutant can be harmful for the respiratory and cardiovascular systems remain unclear. In this article we review the main pathogenic mechanisms proposed to date that make biomass smoke one of the major risk factors for COPD.

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Mecanismos patogénicos en la enfermedad pulmonar obstructiva crónica causada por exposición a humo de biomasa

RESUMEN

Las tasas de mortalidad y morbilidad de la enfermedad pulmonar obstructiva crónica (EPOC) han aumentado mundialmente de forma significativa durante las últimas décadas. A pesar de que el humo de tabaco se sigue considerando el principal factor etiopatogénico para el desarrollo de la enfermedad, se estima que entre una tercera y una cuarta parte de los pacientes con EPOC son no fumadores. De todos los factores de riesgo que pueden incrementar la probabilidad de sufrir EPOC en estos sujetos se ha propuesto al humo de biomasa como uno de los más importantes, afectando sobre todo a mujeres y a niños de países emergentes.

Aunque existen numerosas evidencias epidemiológicas que relacionan la exposición al humo de biomasa con efectos nocivos para la salud, todavía no se conocen bien los mecanismos celulares y moleculares específicos mediante los cuales este contaminante puede suponer una noxa para los sistemas respiratorio y cardiovascular. En esta revisión se recogen los mecanismos patogénicos propuestos hasta la fecha que sitúan al humo de biomasa como uno de los principales factores de riesgo para la EPOC.

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Palabras clave:

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Introduction

Chronic obstructive pulmonary disease (COPD) is a slow, progressive process, characterized by permanent, not fully reversible, airflow obstruction in the bronchioles and by destruction of the pulmonary parenchyma, known as emphysema.¹ The onset of COPD is associated with chronic exposure to toxic gases and particles, in particular tobacco smoke, that triggers an abnormal inflammatory pulmonary and systemic response.^{2–5} However, the causes of the disease are multifactorial, and both genetic disorders and environmental factors may be involved.¹

Although tobacco smoke is still considered the primary risk factor for developing COPD,⁶ a growing body of evidence indicates that between a quarter and a third of COPD cases are diagnosed in non-smokers.⁷ Estimates based on Global Initiative for Lung Disease (GOLD) spirometric criteria suggest that 17%–38.8% of COPD patients worldwide are non-smokers.⁷ In the United States, the United Kingdom, and Spain, rates of COPD in non-smokers are 23%,⁸ 22.9%,⁹ and 23.4%,¹⁰ respectively. Epidemiological studies conducted in developing countries have also revealed a high prevalence of COPD among non-smokers. In the PLATINO study,¹¹ conducted in five cities in Latin America, 26% of all subjects with irreversible airflow obstruction were non-smokers. However, a study conducted in China using similar methodology found an overall prevalence of COPD of only 5.2% among non-smokers.¹²

The most important risk factors that may contribute to the development of COPD in these subjects include genetic predisposition, occupational exposure to dust and chemicals, diet, recurrent respiratory infections in childhood, and air pollution, both indoors and outdoors.¹³ In the latter group, there has been a recent surge of interest in biomass smoke as a significant pollutant in the pathogenesis of COPD.¹³

Biomass Smoke as a Pollutant

Biomass smoke as a source of energy is defined as all organic material from animals or vegetable matter that can be used as fuel. This definition covers a wide range of materials, the most common being wood, agricultural residue, such as branches and dried grass, animal dung, and charcoal.¹⁴ These materials are generally burnt in poorly-ventilated fireplaces and stoves, and generate substantial amounts of harmful pollutants that can reach exposure levels of between 10 and 20 times those recommended by the World Health Organization (WHO).¹⁵

Smoke from burning biomasses contains more than 250 organic compounds that can vary depending on the type of material and combustion conditions.¹⁶ A wide range of gaseous pollutants can be generated, including carbon monoxide, ammonia, hydrocyanic acid, formaldehyde, nitrogen oxides and sulfur, and volatile organic compounds, such as benzene and polycyclic aromatic hydrocarbons (PAH), like benzopyrene. The latter two are potent carcinogens in humans.^{17,18} Moreover, biomass smoke contains a mixture of solid and liquid particles that vary in concentration, size, surface and chemical composition, known as particulate matter (PM).¹⁸ Some particles are respirable and are classified according to their aerodynamic diameter as PM₁₀ (coarse particles with an aerodynamic diameter of 10 µm or less), PM_{2.5} (fine particles with an aerodynamic diameter of 2.5 µm or less) and PM_{0.1} (ultrafine particles with an aerodynamic diameter of 0.1 µm or less). PM₁₀ particles are generally composed of minerals with crystalline or amorphous components and elements absorbed from diverse sources, such as fungi, bacteria or endotoxins.¹⁹ The high transition metal content of PM_{2.5} particles, which generally consist of a carbon nucleus with surface absorption of organic and inorganic components,²⁰ enhances their oxidative stress-generating potential. Ultrafine PM_{0.1} particles, meanwhile, with their high PAH content, are also powerful oxidative stress inducers.^{20,21}

Many studies support the hypothesis that inhalation of these pollutants is harmful to the health and constitutes a risk factor not only for COPD, but also for respiratory infections, asthma, lung cancer, cardiovascular disorders, cataracts, cerebrovascular accidents or even adverse effects on neonatal development.²²

Risk Population

At present, around 50% of the world's population and 90% of homes in rural areas burn biomass as their main source of energy in the home, for cooking or heating.²³ Over 80% of homes in China, India and sub-Saharan Africa use biomass for fuel, while in rural areas in Latin America, the proportion ranges between 30% and 70%.²⁴ Although the use of biomass fuel is particularly extensive in developing countries, the rising cost of fossil fuel, such as petroleum products or natural gas, along with environmental concerns about CO₂ emissions, have also led to an increase in the use of biomass as fuel in developed countries, such as Germany, Finland, Canada, Australia or the United States.^{24–27}

Around 3 billion people worldwide are exposed to biomass smoke, compared to 1 billion tobacco smokers, suggesting that biomass smoke may be a more significant risk factor for developing COPD than tobacco smoke on a worldwide basis.¹⁴ Moreover, for sociocultural reasons, women and children form the main population groups exposed to this pollutant, which is thought to contribute to the death of 2 million women and children globally every year.²⁸ This is because in many developing countries, it is common for women and children to remain at home for long periods, cooking or in close proximity to stoves.

In these settings, women are thought to spend on average over 60 000 h of their life cooking on a biomass stove, during which time they inhale over 25 million liters of polluted air.²³ These data are significant, since it has been shown that respiratory symptoms and airflow limitation increase in line with exposure to biomass smoke.^{29,30} Consequently, several studies have shown that women who use biomass as fuel for cooking have a higher prevalence of respiratory symptoms of COPD than those who do not use this type of fuel.^{31–39} Indeed, 50% of deaths due to COPD in developing countries are attributable to biomass smoke, and 75% of these are in women.⁴⁰

Although COPD mainly affects adults, several studies have shown that many chronic diseases may originate in the development of the fetus and the early years of life.⁴¹ In a recent study, Epstein et al.⁴² found the children of mothers using biomass in their homes had a lower birth weight than those whose mothers used other fuel sources. These results are relevant, since low birth weight, being associated with defective lung development and function during childhood and adulthood, is known to be an independent risk factor for the development of COPD.⁴³ Another study performed in a rural area in India found that forced expiratory volume in 1 second (FEV₁) and forced vital capacity (FVC) were significantly lower in schoolchildren from homes burning biomass fuel than in those from homes using liquefied petroleum gas.⁴⁴ Biomass smoke in indoor environments also increases the risk of respiratory infections.^{45–47} This factor should also be taken into account, since infections in childhood can predispose an individual to developing COPD in adulthood.²⁴

Although women and children are most exposed to biomass smoke, a recent study in 922 COPD patients in 7 cities in Asia found that 31% of men had also been exposed to this pollutant.⁴⁸ Although the percentage is lower than in women (44.8%), the figure is significant. The results of a meta-analysis in Asian and non-Asian subjects revealed that individuals exposed to biomass smoke have a 2.44-fold greater risk of developing COPD than the unexposed population.⁴⁹ Exposure was identified as a risk factor in both men (OR: 4.30; 95% CI: 1.85–10.01) and women (OR: 2.73; 95% CI: 2.28–3.28).⁴⁹ Data from another recent study confirm the association between airflow obstruction in non-smokers and cooking with charcoal in both sexes.⁵⁰

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