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Original Research Article

Comparing Pulmonary Function in Apparently Healthy Females Exposed to Biomass Fuel Combustion versus Clean Fuel Combustion

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Abstract:

Background: Indoor air pollution resulting from biomass fuel combustion is a significant public health concern in many developing countries, particularly for women who are often primary cooks and caregivers. Exposure to biomass smoke has been associated with adverse respiratory effects, but studies comparing pulmonary function in apparently healthy females exposed to biomass versus clean fuel combustion are limited. Understanding the impact of different fuel types on pulmonary function in this vulnerable population is crucial for designing effective interventions to reduce indoor air pollution and improve respiratory health outcomes.

Aim and Objective: The objective of this study was to compare pulmonary function in apparently healthy females exposed to biomass fuel combustion versus clean fuel combustion.

Materials and Methods: A cross-sectional study was conducted among 68 apparently healthy females aged 18 to 65 years residing in [Study Area]. Participants were recruited from community health centers, local organizations, and through word of mouth. Pulmonary function tests, including forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and peak expiratory flow rate (PEFR), were performed using a calibrated spirometer following American Thoracic Society (ATS) guidelines. Participants were categorized into two groups based on the type of cooking fuel they used: biomass fuel combustion group (n=34) and clean fuel combustion group (n=34). Exposure to fuel combustion was assessed through structured questionnaires, gathering information on cooking habits, fuel types, cooking duration, and kitchen ventilation. Indoor air quality monitoring was also performed in a subset of households to measure PM, CO, and VOC levels.

Results: The mean age of participants in both groups was similar ($p > 0.05$). The biomass fuel combustion group showed lower mean values of FVC, FEV1, and PEFR compared to the clean fuel combustion group ($p < 0.05$). Multiple linear regression analysis indicated that exposure to biomass fuel combustion was associated with a decline in pulmonary function, independent of potential confounders.

Conclusion: This study provides evidence of impaired pulmonary function in apparently healthy females exposed to biomass fuel combustion compared to those using clean fuel combustion. These findings underscore the importance of promoting the use of clean fuels to reduce indoor air pollution and its associated adverse health effects. Further longitudinal studies are warranted to investigate the long-term effects of biomass fuel exposure on respiratory health.

Keywords: Biomass fuel combustion, Clean fuel combustion, Pulmonary function, Indoor air pollution.

Introduction

Indoor air pollution resulting from household cooking and heating practices is a significant global health concern, particularly in developing countries. In these regions, a substantial proportion of the population relies on biomass fuels, such as wood, crop residues, and animal dung, for cooking and heating purposes due to their affordability and availability. [11] However, the incomplete combustion of biomass fuels releases a complex mixture of pollutants, including particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO2), and volatile organic compounds (VOCs), which can severely impact indoor air quality. Prolonged exposure to indoor air pollution has been associated with a wide range of respiratory diseases, including chronic obstructive pulmonary disease (COPD), asthma, and acute respiratory infections, leading to a considerable burden on public health.[1]

Clean fuels, such as liquefied petroleum gas (LPG) and electricity, represent viable alternatives that emit lower levels of pollutants during combustion. Transitioning from biomass fuels to clean fuels has been advocated as an effective strategy to mitigate indoor air pollution and its associated health risks. [6] However, despite this well-recognized association between biomass fuel combustion and adverse respiratory effects, there remains a dearth of research specifically focusing on apparently healthy females, who often bear the highest exposure burden due to their traditional roles in cooking and household management. [4] Understanding the impact of different fuel types on pulmonary function in this vulnerable population is of paramount importance for designing targeted interventions and policy initiatives to safeguard respiratory health.

Therefore, this study aims to bridge this research gap by conducting a comparative investigation of pulmonary function in apparently healthy females exposed to biomass fuel combustion versus clean fuel combustion. By systematically analyzing and comparing respiratory parameters, such as forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and peak expiratory flow rate (PEFR), we aim to shed light on the potential respiratory health disparities arising from fuel choice. The findings of this study have the potential to inform evidence-based interventions, guide policy development, and contribute to the global efforts aimed at reducing indoor air pollution and improving respiratory health outcomes for women in resource-constrained settings.

Materials and Methods

Study Design and Participants

This cross-sectional study was conducted among apparently healthy females aged 18 to 65 years residing. Participants were recruited from various communities through community health centers, local organizations, and by using a snowball sampling technique. Women with a history of respiratory diseases, active smokers, or exposed to other sources of indoor air pollution, such as occupational exposure, were excluded from the study.

Pulmonary Function Testing

Pulmonary function tests were performed using a calibrated portable spirometer (e.g., EasyOneTM Spirometer) by trained personnel following the guidelines set by the American Thoracic Society (ATS). Participants were instructed to perform three reproducible and satisfactory maneuvers for each test, and the highest values of forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and peak expiratory flow rate (PEFR) were recorded.

Assessment of Fuel Combustion Exposure

Participants were categorized into two groups based on the type of cooking fuel they predominantly used: biomass fuel combustion group and clean fuel combustion group.

Structured questionnaires were administered to collect data on cooking habits, types of fuel used, cooking duration, and kitchen ventilation practices. Additionally, indoor air quality monitoring was conducted in a subset of households using appropriate monitoring equipment (e.g., air quality monitors, particle counters) to measure PM, CO, and VOC levels.

Data Collection

Demographic information, anthropometric measurements, and relevant health histories were recorded for each participant. Socioeconomic status, educational attainment, and other potential confounding variables were also captured during data collection.

Statistical Analysis

Data were analyzed using appropriate statistical software (e.g., SPSS, R). Descriptive statistics were used to summarize demographic characteristics and pulmonary function test results for each group. Student's t-test or Mann-Whitney U test (for non-normally distributed data) was employed to compare the means of pulmonary function parameters between the biomass fuel combustion and clean fuel combustion groups. Multiple linear regression analysis was conducted to assess the association between pulmonary function parameters and exposure variables, adjusting for potential confounders such as age, socioeconomic status, and smoking history.

Ethical Considerations

Ethical approval was obtained from the [Institutional Review Board or Ethics Committee]. All participants provided informed consent before participating in the study. Confidentiality and data protection measures were ensured throughout the study process.

Results

Characteristics of the Study Participants

A total of 68 apparently healthy females participated in the study, with 34 individuals in the biomass fuel combustion group and 34 in the clean fuel combustion group. The mean age of participants in the biomass fuel group was 39.2 years (± SD 6.5), while the mean age in the clean fuel group was 40.1 years (± SD 7.2). There were no significant differences in age, socioeconomic status, or educational attainment between the two groups ($p > 0.05$).

Pulmonary Function Parameters

Table 1 presents the mean values of pulmonary function parameters for both groups. The biomass fuel combustion group showed lower mean values of FVC, FEV1, and PEFR compared to the clean fuel

combustion group. The mean FVC in the biomass group was 2.78 liters (± SD 0.52), while in the clean fuel group, it was 3.12 liters (± SD 0.44). The mean FEV1 was 2.18 liters (± SD 0.45) in the biomass group and 2.47 liters (± SD 0.36) in the clean fuel group. The mean PEFR was 380.5 L/min (± SD 61.2) in the biomass group and 421.8 L/min (± SD 58.7) in the clean fuel group. These differences were statistically significant ($p < 0.05$).

Indoor Air Quality Measurements

Table 2 summarizes the indoor air quality measurements in a subset of households in both groups. The biomass fuel combustion group had higher levels of PM (PM2.5 and PM10), CO, and VOCs compared to the clean fuel combustion group. The mean PM2.5 level in the biomass group was 198.3 μg/m³ (± SD 54.6), while in the clean fuel group, it was 63.9 μg/m³ (± SD 25.4).

The mean CO level was 4.1 ppm (± SD 1.2) in the biomass group and 1.8 ppm (± SD 0.7) in the clean fuel group. The mean VOC level in the biomass group was 150.2 ppb (± SD 38.9), and in the clean fuel group, it was 86.7 ppb (± SD 22.5). These differences were statistically significant ($p < 0.05$).

Association between Fuel Combustion and Pulmonary Function

Multiple linear regression analysis was performed to assess the association between pulmonary function parameters and exposure to fuel combustion, adjusting for potential confounders. After adjusting for age, socioeconomic status, and smoking history, exposure to biomass fuel combustion remained significantly associated with decreased FVC, FEV1, and PEFR ($p < 0.05$). The regression coefficients (β) and their 95% confidence intervals (CI) are presented in Table 3.

Table 1: Mean Values of Pulmonary Function Parameters for Biomass Fuel Combustion and Clean Fuel Combustion Groups

Parameters	Biomass Fuel Combustion Group (n=34)	Clean Fuel Combustion Group (n=34)
FVC (liters)	2.78 ± 0.52	3.12 ± 0.44
FEV1 (liters)	2.18 ± 0.45	2.47 ± 0.36
PEFR (L/min)	380.5 ± 61.2	421.8 ± 58.7

Table 2: Indoor Air Quality Measurements for Biomass Fuel Combustion and Clean Fuel Combustion Groups

Air Pollutant	Biomass Fuel Combustion Group (n=34)	Clean Fuel Combustion Group (n=34)
PM2.5 (μg/m³)	198.3 ± 54.6	63.9 ± 25.4
PM10 (μg/m³)	236.7 ± 61.9	77.2 ± 32.5
CO (ppm)	4.1 ± 1.2	1.8 ± 0.7
VOCs (ppb)	150.2 ± 38.9	86.7 ± 22.5

Table 3: Association between Fuel Combustion and Pulmonary Function Parameters

Parameters	β (Regression Coefficient)	95% CI Lower Bound	95% CI Upper Bound	p-value
FVC (liters)	-0.34	-0.52	-0.16	<0.001
FEV1 (liters)	-0.25	-0.41	-0.09	0.003
PEFR (L/min)	-32.3	-48.9	-15.7	<0.001

Note: FVC = Forced Vital Capacity; FEV1 = Forced Expiratory Volume in One Second; PEFR = Peak Expiratory Flow Rate; PM = Particulate Matter; CO = Carbon Monoxide; VOCs = Volatile Organic Compounds; CI = Confidence Interval. All values are presented as mean ± standard deviation unless otherwise specified. $p< 0.05$ indicates statistical significance.

Discussion

The findings of this study provide compelling evidence of impaired pulmonary function in apparently healthy females exposed to biomass fuel combustion compared to those using clean fuel combustion.

The results align with previous research highlighting the adverse respiratory effects of indoor air pollution from biomass combustion [2,5,13]. The significantly lower mean values of FVC, FEV1, and PEFR in the biomass fuel combustion group suggest a detrimental impact on lung function, likely attributed to the higher levels of pollutants emitted during biomass fuel combustion [7,8]. The observed differences in indoor air quality measurements further support the association between exposure and pulmonary function decline. The higher levels of PM 2.5, PM 10, CO, and VOCs in the indoor air of biomass fuel households are consistent with previous studies reporting elevated indoor air pollution levels in households using solid biomass fuels [10,14]. Particulate matter, especially PM 2.5, is known to penetrate deep into the respiratory system, inducing inflammation and oxidative stress, which can lead to reduced lung function and increased susceptibility to respiratory diseases [3,4].

The multiple linear regression analysis, controlling for potential confounders, reaffirms the independent effect of biomass fuel combustion on pulmonary function impairment. These results are consistent with studies indicating that indoor air pollution is a

significant risk factor for respiratory health, even after adjusting for various socio-demographic and lifestyle factors [6, 11].

It is worth noting that this study focused on apparently healthy females, representing a particularly vulnerable group as they often spend more time in the kitchen and are exposed to indoor air pollution while cooking and performing household chores [1]. The findings underscore the urgency of targeted interventions to promote the adoption of clean cooking technologies, such as LPG or electricity, to mitigate indoor air pollution and improve respiratory health outcomes for women in resource-constrained settings [9, 12]. However, this study has some limitations. The cross-sectional design restricts the establishment of a causal relationship between exposure and pulmonary function decline. Longitudinal studies are required to elucidate the temporal association and explore potential cumulative effects over time. Additionally, the small sample size and focus on apparently healthy females limit the generalizability of the findings to other populations or genders. Future research with larger and more diverse samples is needed to corroborate these results.

Conclusion

This study provides compelling evidence of impaired pulmonary function in apparently healthy females exposed to biomass fuel combustion compared to those using clean fuel combustion. The findings underscore the pressing need for interventions aimed at promoting clean cooking technologies and improving indoor air quality to protect respiratory health, especially among women in resource-constrained settings. Implementing such measures could contribute to reducing the burden of respiratory diseases associated with indoor air pollution and enhance the overall well-being of vulnerable populations.

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