



doi • 10.5578/tt.2025011018  
Tuberk Toraks 2025;73(1):20-27  
Received: 12.12.2024 • Accepted: 05.03.2025

RESEARCH ARTICLE

# Impact of chronic biomass smoke exposure on pulmonary function and respiratory health in elderly women: A rural perspective

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**Cite this article as:** Turan B, Çelik Y, Olgun Yıldızeli Ş, Kaptan Y, Balcan B. Impact of chronic biomass smoke exposure on pulmonary function and respiratory health in elderly women: A rural perspective. Tuberk Toraks 2025;73(1):20-27.

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**Data Sharing Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## ABSTRACT

### Impact of chronic biomass smoke exposure on pulmonary function and respiratory health in elderly women: A rural perspective

**Introduction:** Chronic exposure to biomass smoke is a significant health concern, particularly in rural areas where women are primarily responsible for household cooking using organic fuels. This study aimed to evaluate the impact of biomass smoke exposure on pulmonary function and its associated risk factors among elderly women.

**Materials and Methods:** A total of 474 women were screened, of whom 115 were exclusively exposed to biomass smoke, and 32 participants aged ≥65 years were included in the elderly cohort. Pulmonary function tests were performed using a calibrated spirometer, assessing reduced forced expiratory volume in 1 second (FEV<sub>1</sub>), forced vital capacity (FVC), and FEV<sub>1</sub>/FVC ratio. Logistic and linear regression analyses were conducted to explore the relationship between pulmonary outcomes and exposure duration, demographic characteristics, and comorbidities.

**Results:** Among all participants, obstructive lung disease (FEV<sub>1</sub>/FVC < 70%) was observed in 84.3%, while restrictive patterns were found in 16.7%. Prolonged biomass smoke exposure was significantly associated with lower FEV<sub>1</sub>, FVC, and FEV<sub>1</sub>/FVC ratios ( $p < 0.001$ ). Multivariate logistic regression identified exposure duration as an independent predictor of obstruction [Odds ratio (OR)= 1.25, 95% confidence interval (CI)= 1.08-1.44,  $p < 0.001$ ]. In the elderly subgroup, logistic regression confirmed a significant association between biomass exposure duration and obstruction (OR= 1.26, 95% CI= 1.02-1.57,  $p = 0.035$ ), while linear regression revealed a negative correlation between exposure duration and FEV<sub>1</sub>/FVC ratio ( $\beta = -0.65$ , 95% CI= -0.09 to

-0.03,  $p < 0.001$ ).

**Conclusion:** Prolonged exposure to biomass smoke is strongly associated with deteriorated pulmonary function, particularly among elderly women. These findings underscore the urgent need for targeted interventions to reduce biomass smoke exposure and improve respiratory health in vulnerable rural populations.

**Key words:** Biomass; pulmonary function test; chronic obstructive pulmonary disease

## ÖZ

**Kronik biyokütle dumanına maruz kalan yaşlı kadınlarda akciğer fonksiyonu ve solunum sağlığı üzerindeki etkisi: Kırsal perspektif**

**Giriş:** Biyokütle dumanına kronik maruziyet, özellikle kırsal bölgelerde organik yakıtlarla yemek pişiren kadınlar için önemli bir sağlık sorunudur. Bu çalışma, biyokütle dumanına maruziyetin yaşlı kadınlarda akciğer fonksiyonları üzerindeki etkisini ve ilişkili risk faktörlerini değerlendirmeyi amaçlamaktadır.

**Materyal ve Metod:** Toplam 474 kadın taranmış, bunlardan yalnızca biyokütle dumanına maruz kalan 115 kişi seçilmiştir. Çalışmaya, 65 yaş ve üzeri 32 katılımcı yaşlılar grubuna dahil edilmiştir. Akciğer fonksiyon testleri, zorlu ekspirasyonun birinci saniyedeki volümü ( $FEV_1$ ), zorlu vital kapasite (FVC) ve  $FEV_1/FVC$  oranını değerlendiren kalibre edilmiş bir spirometre kullanılarak gerçekleştirilmiştir. Akciğer fonksiyonları ile maruziyet süresi, demografik özellikler ve komorbiditeler arasındaki ilişkiyi incelemek için lojistik ve doğrusal regresyon analizleri yapılmıştır.

**Bulgular:** Obstrüktif akciğer hastalığı ( $FEV_1/FVC < \%70$ ), tüm katılımcılar arasında %84.3 oranında gözlenirken, restriktif paternler %16.7 oranında tespit edilmiştir. Uzun süreli biyokütle dumanı maruziyeti,  $FEV_1$ , FVC ve  $FEV_1/FVC$  oranlarının düşüklüğü ile anlamlı şekilde ilişkili bulunmuştur ( $p < 0.001$ ). Çok değişkenli lojistik regresyon analizine göre, maruziyet süresi obstrüksiyonun bağımsız bir belirleyicisi olarak tanımlanmıştır [Olabilirlik oranı testi (OOT)= 1.25; %95 güven aralığı (GA)= 1.08-1.44;  $p < 0.001$ ]. Yaşlı alt grupta yapılan lojistik regresyon analizi, biyokütle maruziyet süresi ile obstrüksiyon arasında anlamlı bir ilişki göstermiştir (OOT= 1.26; %95 GA= 1.02-1.57;  $p = 0.035$ ). Doğrusal regresyon analizi ise maruziyet süresi ile  $FEV_1/FVC$  oranı arasında negatif bir korelasyon ortaya koymuştur ( $\beta = -0.65$ ; %95 GA= -0.09 ile -0.03;  $p < 0.001$ ).

**Sonuç:** Uzun süreli biyokütle dumanı maruziyeti, özellikle yaşlı kadınlarda akciğer fonksiyonlarının bozulmasıyla güçlü bir şekilde ilişkilidir. Bu bulgular, biyokütle dumanına maruziyeti azaltmaya yönelik hedefli müdahalelerin gerekliliğini ve kırsal bölgelerde yaşayan kırılgan nüfusun solunum sağlığını iyileştirmek için acil önlemler alınması gerektiğini vurgulamaktadır.

**Anahtar kelimeler:** Biyokütle; solunum fonksiyon testi; kronik obstrüktif akciğer hastalığı

## INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a significant global health concern, particularly in low- and middle-income countries where biomass fuel usage is prevalent (1,2). In these regions, women are disproportionately affected due to their primary role in cooking with solid fuels such as wood, charcoal, and dung in poorly ventilated environments (3). This exposure leads to substantial respiratory health challenges, including the development of COPD, which is among the leading causes of death worldwide (4). Biomass smoke contains harmful substances such as particulate matter (PM), carbon monoxide (CO), nitrogen oxides, and volatile organic compounds (5). Prolonged exposure to these pollutants has been associated with both obstructive and restrictive lung diseases, mirroring the pathophysiology observed in cigarette smoke-induced lung damage (3,6). The mechanisms by which biomass smoke leads to respiratory disease include chronic inflammation and oxidative stress in the lungs, resulting in obstruction and restriction of airflow (7). Furthermore, biomass smoke exposure has been linked to comorbidities such as hypertension, heart disease, and diabetes,

which can exacerbate respiratory decline (8). Evidence suggests that women exposed to biomass smoke may experience declines in lung function similar to those seen in smokers, characterized by reduced forced expiratory volume in 1 second ( $FEV_1$ ), forced vital capacity (FVC), and an elevated risk of developing COPD, and there is urgent need for targeted public health interventions aimed at reducing biomass smoke exposure among women in rural areas (9-11).

Individuals over 65 years of age exposed to biomass smoke experience an accelerated decline in respiratory function, contributing to a more rapid progression of respiratory dysfunction (12). The Global Burden of Disease study emphasizes that elderly women, particularly in rural settings, are at the highest risk for biomass smoke-related respiratory diseases (13). While the detrimental effects of biomass smoke on respiratory health have been well documented, few studies have specifically examined its impact on elderly women. This study aims to assess the pulmonary function of elderly women exposed to biomass smoke in rural areas, investigating the prevalence of obstructive lung conditions, as well as examine



demographic and comorbid factors associated with impaired lung function in this vulnerable population.

## MATERIALS and METHODS

### Participants

In the village of Kağızman, a borough of Kars in eastern Türkiye, a longstanding tradition designates women as responsible for baking bread within their households. This activity is often carried out under poor ventilation and in the absence of chimneys, resulting in significant exposure to smoke. Organic waste materials, particularly dried animal dung (manure), are commonly used as fuel sources instead of wood or charcoal. The primary inclusion criterion for the study was the screening of pulmonary functions in females with direct exposure to biomass smoke. Field visits to the village was conducted and evaluated a total of 474 females who met the exposure criteria. To ensure the accuracy of pulmonary

function test (PFT) results and minimize confounding factors, individuals with certain conditions or comorbidities were excluded. Those were with a history of smoking, cardiovascular diseases, renal failure, asthma or allergic conditions and participants who had received treatment for upper or lower respiratory infections within the past month. Moreover, women with chronic pulmonary conditions, such as interstitial lung disease or bronchiectasis, significant thoracic deformities, such as kyphoscoliosis; neuromuscular disorders were also excluded (Figure 1). After applying these criteria, the final study cohort consisted of 115 females who were exclusively exposed to biomass smoke, of whom 32 women aged 65 years or older were identified and included in the study protocol (Figure 1). All the research procedures were approved by the local ethics committee of the Public Health Directorship in Kars, and all participants provided written consent for the study.

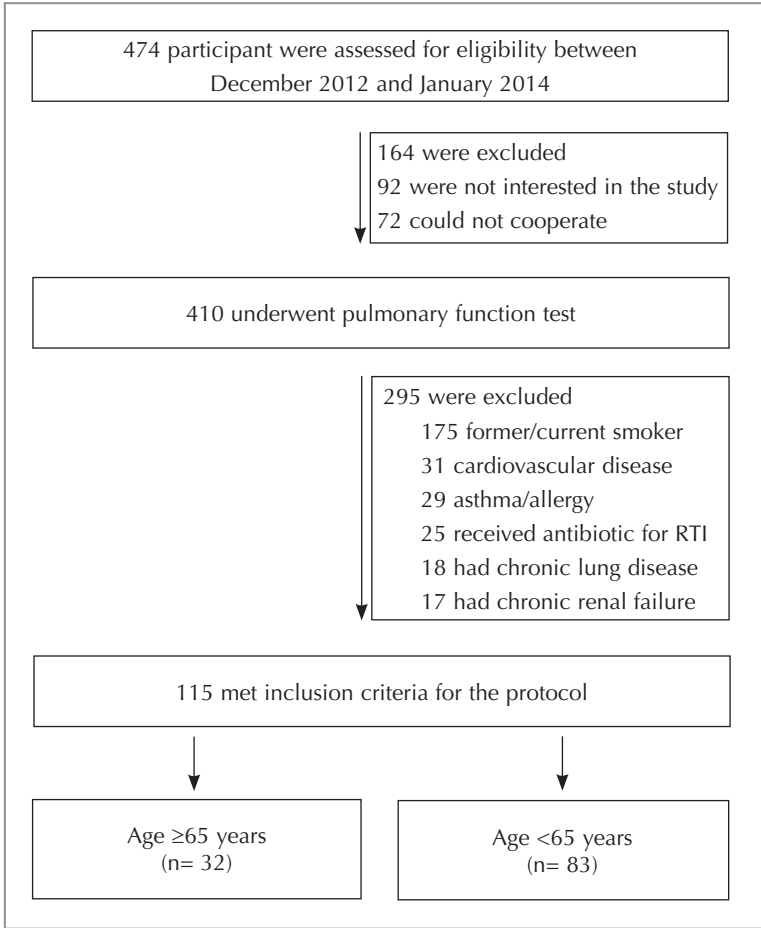


Figure 1. Flow chart of the participants.

## Pulmonary function testing

PFTs were performed using a calibrated Spirolab III device (MIR, Waukesha, WI, USA) under the supervision of a trained technician. Measurements included FEV<sub>1</sub>, FVC, and FEV<sub>1</sub>/FVC ratio. These parameters were recorded for both the study and control groups. PFT results were categorized following the guidelines of the European Respiratory Society and the American Thoracic Society and value of FEV<sub>1</sub>/FVC ratio below 70% was categorized as obstructive lung disease.

## Statistics

Continuous variables, such as age and BMI, were reported as mean  $\pm$  standard deviation, while categorical variables were expressed as frequencies and percentages. Comparisons between the groups were performed using independent-sample t-tests for normally distributed continuous variables and the Mann-Whitney U test for non-normally distributed variables. Chi-square or Fisher's exact tests were used for categorical variables. Univariate logistic regression was used to evaluate the association between biomass smoke exposure duration and the presence of COPD. Variables with  $p < 0.05$  in univariate regression analysis were included in the multivariate regression model, which was adjusted for confounding factors. Odds ratios (ORs),  $\beta$  co-efficient with 95% confidence intervals (CIs) were reported to quantify the strength of associations. A  $p < 0.05$  was considered statistically significant. All statistical analyses were performed using SPSS 28 (version 28.0 IBM Corp., Armonk, NY, USA).

## RESULTS

As described in Table 1, we compared pulmonary function, comorbidities, and exposure characteristics between women aged 65 years or older and those younger than 65 years. Mean age in the older group was significantly higher ( $71.0 \pm 6.1$  years) compared to the younger group ( $33.3 \pm 12.5$  years;  $p < 0.001$ ). The starting age of biomass exposure did not differ significantly between the two groups ( $17.92 \pm 3.21$  years vs.  $18.87 \pm 3.43$  years;  $p = 0.214$ ). Hypertension was markedly more prevalent in the older group (84.6%) compared to the younger group (15.4%;  $p < 0.001$ ), as was diabetes mellitus (34.6% vs. 6.7%;  $p < 0.001$ ). An obstructive pulmonary pattern (FEV<sub>1</sub>/FVC < 70%) was significantly more common among women aged 65 years or older (76.9%) than in those younger than 65 years (15.7%;  $p < 0.001$ ). The duration of biomass smoke exposure was also significantly longer in the older group ( $41.1 \pm 11.8$  years) compared to the younger group ( $14.1 \pm 11.9$  years;  $p < 0.001$ ). PFT results revealed that the older group had significantly lower FEV<sub>1</sub>/FVC ratios ( $0.67 \pm 0.12$  vs.  $0.83 \pm 0.09$ ;  $p < 0.001$ ), FEV<sub>1</sub> percentages ( $40.23 \pm 9.72\%$  vs.  $66.79 \pm 11.99\%$ ;  $p < 0.001$ ), and FVC percentages ( $59.15 \pm 8.25\%$  vs.  $59.15 \pm 8.25\%$ ;  $p < 0.001$ ) compared to the younger group (Figure 2).

In Table 2, a multivariate logistic regression analysis was conducted to evaluate factors associated with obstructive pulmonary patterns among all participants. Variables that were significant in the univariate analysis were included in the multivariate model, and we observed that the duration of biomass smoke exposure was significantly associated with obstruction (OR= 1.25, 95% CI= 1.08-1.44,  $p < 0.001$ ).

**Table 1.** Comparison of demographic characteristics, comorbidities, and pulmonary function parameters between women aged  $\geq 65$  years and  $< 65$  years

|                        | Age $\geq 65$ years (n= 32) | Age $< 65$ years (n= 83) | p         |
|------------------------|-----------------------------|--------------------------|-----------|
| Age, years             | $71.0 \pm 6.1$              | $33.3 \pm 12.5$          | $< 0.001$ |
| Starting age           | $17.92 \pm 3.21$            | $18.87 \pm 3.43$         | 0.214     |
| Hypertension, %        | 84.6                        | 15.4                     | $< 0.001$ |
| Diabetes mellitus, %   | 34.6                        | 6.7                      | $< 0.001$ |
| Obstructive pattern, % | 76.9                        | 15.7                     | $< 0.001$ |
| Duration, years        | $41.1 \pm 11.8$             | $14.1 \pm 11.9$          | $< 0.001$ |
| FEV <sub>1</sub> /FVC  | $0.67 \pm 0.12$             | $0.83 \pm 0.09$          | $< 0.001$ |
| FEV <sub>1</sub> , %   | $40.23 \pm 9.72$            | $66.79 \pm 11.99$        | $< 0.001$ |
| FVC, %                 | $59.15 \pm 8.25$            | $59.15 \pm 8.25$         | $< 0.001$ |

FEV<sub>1</sub>: Forced expiratory volume in 1 second, FVC: Forced vital capacity.

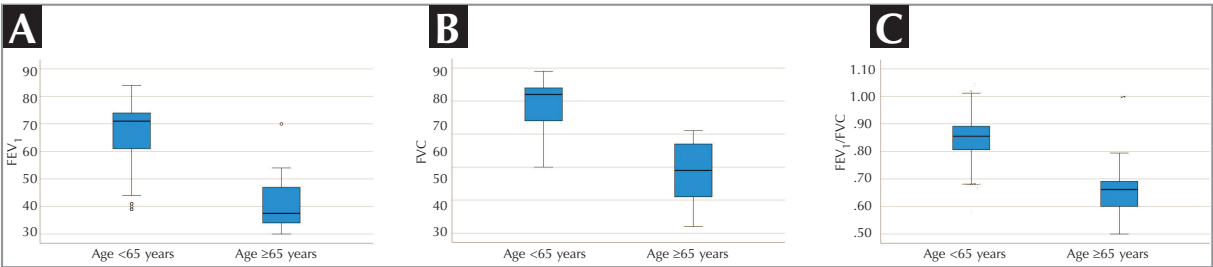


**Figure 2.** Comparison of pulmonary function test parameters (FEV<sub>1</sub>, FVC, and FEV<sub>1</sub>/FVC) between participants aged <65 years and ≥65 years.

| Table 2. Multivariate logistic regression analysis of factors associated with obstruction among all participants |             |                  |                  |
|------------------------------------------------------------------------------------------------------------------|-------------|------------------|------------------|
|                                                                                                                  | OR          | 95% CI           | p                |
| Age                                                                                                              | 1.18        | 0.97-1.43        | 0.083            |
| Age ≥65 years                                                                                                    | 0.04        | 0.01-2.07        | 0.108            |
| Hypertension                                                                                                     | 0.47        | 0.04-6.18        | 0.565            |
| Diabetes mellitus                                                                                                | 1.62        | 0.15-18.11       | 0.695            |
| <b>Duration</b>                                                                                                  | <b>1.25</b> | <b>1.08-1.44</b> | <b>&lt;0.001</b> |

OR: Odds ratio, CI: Confidence interval.

| Table 3. Linear regression FEV <sub>1</sub> /FVC ratio among all participants |                |                       |                  |
|-------------------------------------------------------------------------------|----------------|-----------------------|------------------|
|                                                                               | β co-efficient | 95% CI                | p                |
| Age                                                                           | -0.14          | -0.03-0.01            | 0.380            |
| Elderly                                                                       | 0.08           | -0.04-0.08            | 0.417            |
| Hypertension                                                                  | 0.06           | -0.04-0.07            | 0.546            |
| Diabetes mellitus                                                             | -0.05          | -0.06-0.02            | 0.412            |
| <b>Duration</b>                                                               | <b>-0.78</b>   | <b>-0.08 to -0.04</b> | <b>&lt;0.001</b> |

CI: Confidence interval.

Other factors, including age, being aged ≥65 years, hypertension, and diabetes mellitus, were not statistically significant in this model.

As illustrated in Table 3, a multivariate linear regression analysis was performed to assess the relationship between FEV<sub>1</sub>/FVC ratio by adjusting the factors that were significant in the univariate model. Among the variables analyzed, the duration of biomass smoke exposure showed a significant negative association

with the FEV<sub>1</sub>/FVC ratio (β = -0.78, 95% CI= -0.08 to -0.04, p< 0.001), indicating that longer exposure was associated with a greater decline in this parameter. Other factors, including age, being elderly, hypertension, and diabetes mellitus lost their significance in the multivariate analysis.

In Table 4 and Table 5, associates of obstruction and change in FEV<sub>1</sub>/FVC ratios were assessed. Among the variables analyzed, the duration of biomass smoke

| Table 4. Logistic regression analysis of factors associated with obstruction among elderly participants |             |                  |              |
|---------------------------------------------------------------------------------------------------------|-------------|------------------|--------------|
|                                                                                                         | OR          | 95% CI           | p            |
| Age                                                                                                     | 1.32        | 0.90-1.47        | 0.124        |
| Hypertension                                                                                            | 0.06        | 0.01-7.96        | 0.262        |
| Diabetes mellitus                                                                                       | 0.11        | 0.03-4.52        | 0.247        |
| <b>Duration</b>                                                                                         | <b>1.26</b> | <b>1.02-1.57</b> | <b>0.035</b> |

OR: Odds ratio, CI: Confidence interval.

**Table 5.** Linear regression analysis of factors associated with FEV<sub>1</sub>/FVC ratio among elderly participants

|                   | $\beta$ co-efficient | 95% CI                | p                |
|-------------------|----------------------|-----------------------|------------------|
| Age               | -0.05                | -0.07 to -0.05        | 0.748            |
| Hypertension      | 0.25                 | -0.02-0.19            | 0.118            |
| Diabetes mellitus | -0.05                | -0.08-0.06            | 0.754            |
| <b>Duration</b>   | <b>-0.65</b>         | <b>-0.09 to -0.03</b> | <b>&lt;0.001</b> |

CI: Confidence interval.

exposure was significantly associated with obstruction (OR= 1.26, 95% CI= 1.02-1.57,  $p= 0.035$ ) and decline in the FEV<sub>1</sub>/FVC ratio ( $\beta= -0.65$ , 95% CI= -0.09 to -0.03,  $p< 0.001$ ). Other factors, including age, hypertension and diabetes mellitus were not significantly associated with the obstruction as well as decline in FEV<sub>1</sub>/FVC ratio.

## DISCUSSION

The present study examines the impact of prolonged biomass smoke exposure on pulmonary function among women, with a particular focus on those aged 65 years and older. Our findings indicate that elderly women exhibit significantly lower pulmonary function parameters, and a higher prevalence of obstructive lung patterns compared to their younger counterparts.

Mean age of biomass smoke exposure initiation did not differ significantly between the two groups, suggesting that the duration of exposure, rather than the age at which exposure began, plays a more critical role in pulmonary function decline. This is consistent with existing literature indicating that cumulative exposure to biomass smoke is a significant risk factor for developing chronic respiratory conditions, such as COPD (14). The higher prevalence of comorbidities, such as hypertension and diabetes mellitus, among the older cohort aligns with general epidemiological trends observed in aging populations. However, the interplay between these comorbidities and biomass smoke exposure may exacerbate respiratory decline, as systemic conditions like hypertension and diabetes can adversely affect lung function and amplify the detrimental effects of environmental pollutants (15). The significantly lower FEV<sub>1</sub>, FVC, and FEV<sub>1</sub>/FVC ratios observed in the elderly group underscore the severe impact of prolonged biomass smoke exposure on lung function. These findings are in line with previous studies that have reported similar declines in pulmonary function among individuals exposed to biomass smoke, inde-

pendent of smoking status (16-18). The predominance of obstructive lung patterns in the older group suggests that biomass smoke exposure may lead to airway obstruction, a hallmark of COPD. This is corroborated by studies indicating that biomass smoke exposure increases the risk of developing COPD, with a significant association observed between biomass smoke exposure and COPD in both rural and urban women (14).

The duration of biomass smoke exposure emerged as the only significant factor associated with an increased likelihood of obstruction. This finding reinforces the established link between prolonged biomass smoke exposure and obstructive lung diseases, such as COPD, a relationship supported by prior studies demonstrating that biomass exposure independently contributes to the development of COPD in non-smoking populations (19-21). Other variables such as demographics and comorbidities were not significant predictors of COPD, these findings suggest that the adverse effects of biomass smoke exposure on pulmonary obstruction are not primarily mediated by those factors but are directly attributable to the cumulative exposure itself (3,22). The accumulation of harmful PM 2.5, CO, and other toxic compounds from biomass combustion induces chronic airway inflammation, oxidative stress, and structural damage, leading to progressive respiratory impairment (23).

Prolonged biomass smoke exposure on pulmonary health outcomes among elderly women has also been evaluated, and the duration of biomass smoke exposure has been reported as a significant predictor of obstructive pulmonary patterns among participants over 65 years. This finding aligns with the existing literature indicating that cumulative exposure to biomass smoke is a critical, moreover an independent risk factor for developing COPD (15). Other variables such as age, hypertension, and diabetes mellitus were not significant predictors in this model, and this

suggests that the adverse effects of biomass smoke exposure on pulmonary obstruction are primarily attributable to the cumulative exposure itself, rather than being mediated by demographic or comorbid factors.

This study has several limitations that warrant consideration. The cross-sectional design prevents establishing a causal relationship between biomass smoke exposure and pulmonary function decline. Additionally, self-reported data on the duration and intensity of exposure may be subject to recall bias, potentially affecting the accuracy of the exposure assessment. The study was conducted in a single rural region, which may limit the generalizability of the findings to other populations with differing environmental and socio-economic conditions. Furthermore, the sample size of elderly participants, while adequate for statistical analysis, may not capture the full variability of pulmonary outcomes across broader populations. Last, while efforts were made to control for confounders such as age and comorbidities, unmeasured factors like dietary habits, genetic predispositions, or co-exposures (e.g., occupational hazards) could influence the results. Future studies with longitudinal designs, larger sample sizes, and more detailed exposure assessments are recommended to build on these findings.

This study highlights the significant impact of prolonged biomass smoke exposure on pulmonary function, particularly among elderly women in rural settings. The findings demonstrate that cumulative exposure is strongly associated with both obstructive pulmonary patterns and reduced FEV<sub>1</sub>/FVC ratios, independent of other demographic or comorbid factors. These results emphasize the urgent need for targeted public health interventions, including the promotion of cleaner cooking technologies, improved ventilation, and educational programs to reduce biomass smoke exposure. By addressing this critical environmental health issue, policymakers can help mitigate the burden of chronic respiratory diseases and improve the quality of life for vulnerable populations.

**Ethical Committee Approval:** This study was approved by the Ethics Committee of the Kars Provincial Directorate of Health, Public Health Unit (Decision no: 7.2013.08, Date: 23.05.2013).

## CONFLICT of INTEREST

The authors declare that they have no conflict of interest.

## AUTHORSHIP CONTRIBUTIONS

Concept/Design: BT, BB

Analys/Interpretation: BB, YC

Data acquisition: YC

Writing: YK, SOY, BB

Clinical Revision: SOY, BB

Final Approval: All of authors

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