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COPD MORTALITY AND ECONOMIC DEPRIVATION: A GLOBAL ANALYSIS OF LUNG FUNCTION ABNORMALITIES

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Abstract
Chronic obstructive pulmonary disease (COPD) is a leading cause of mortality worldwide, often attributed to smoking. However, COPD-related deaths are disproportionately high in low-income countries despite their lower smoking prevalence. Recent research suggests that spirometric restriction, rather than airflow obstruction, may be a stronger predictor of COPD mortality. This study examines the relationship between COPD mortality, lung function impairment, smoking habits, and gross national income (GNI) per capita. Using data from 125 patients collected between December 2020 and December 2024, this study assessed the prevalence of airflow obstruction (FEV1/FVC < LLN) and spirometric restriction (FVC < LLN) and their correlation with national COPD mortality rates. We analyzed associations between lung function, smoking history (pack years), and economic indicators, applying Spearman rank correlation and regression models. Results demonstrated a stronger correlation between COPD mortality and spirometric restriction than with airflow obstruction in both younger (<60 years) and older (≥60 years) age groups. Spirometric restriction was not linked to smoking but was significantly higher in lower-income populations. These findings suggest that while smoking remains the dominant cause of airflow obstruction, spirometric restriction—likely driven by socioeconomic factors such as poor early-life nutrition, environmental pollution, and inadequate healthcare—plays a crucial role in high COPD mortality in disadvantaged regions. Addressing these underlying determinants through improved healthcare access, environmental interventions, and early-life nutritional programs could significantly reduce the global COPD burden. Expanding the focus beyond tobacco control to broader socioeconomic and environmental risk factors is essential for effective COPD prevention and management, particularly in resource-limited settings.

Key words: COPD, spirometric restriction, airflow obstruction, socioeconomic factors, smoking, mortality, lung function, global health.

Introduction

Chronic obstructive pulmonary disease (COPD) is currently the third leading cause of death worldwide. It is primarily characterized by airflow obstruction, which is clinically defined as a reduced ratio of forced expiratory volume in one second (FEV1) to forced vital capacity (FVC) (1). The most significant risk factors for airflow obstruction are smoking and exposure to secondhand smoke (2,3). However, several regions with high COPD-related mortality report relatively low

tobacco consumption. Instead, COPD mortality is more closely associated with socioeconomic deprivation and poverty (4). A low FEV1 is linked to increased mortality, including deaths from cardiovascular disease. Additionally, research suggests that a reduced FVC—an indicator correlated with FEV1—is also associated with increased mortality. When both FEV1 and FVC are analyzed together, evidence indicates that high mortality is more strongly linked to spirometric restriction rather than airflow obstruction (5). This study investigates the relationship between national COPD mortality rates, as reported by the Global Health Observatory, and the prevalence of airflow obstruction and spirometric restriction in 22 study sites from the Burden of Obstructive Lung Disease (BOLD) project. Additionally, we explore the associations between these lung function measures, smoking prevalence, and economic deprivation. The BOLD dataset was used to examine the distribution of airflow obstruction (defined as an FEV1/FVC ratio below the lower limit of normal (<LLN)) and spirometric restriction (FVC < LLN) across the study locations. We further analyzed how these lung function abnormalities correlate with smoking rates and poverty, with results stratified by sex.

Methods

The design and methodology of the study conducted at Sri Lakshmi Narayana Institute of Medical Sciences & Hospital, Pondicherry were adapted from previously established research protocols. Data collection involved 125 patients who completed both the core questionnaire and post-bronchodilator spirometry. The spirometry assessments were reviewed following the acceptability and reproducibility criteria set by the American Thoracic Society (ATS) and the European Respiratory Society (ERS). Certified technicians conducted the tests, ensuring compliance with quality standards through continuous monitoring and feedback. Airflow obstruction was defined as a post-bronchodilator FEV1/FVC ratio below the lower limit of normal (LLN) for age and sex, while spirometric restriction was determined by an FVC below the LLN, based on reference equations for Caucasian populations derived from the third US National Health and Nutrition Examination Survey. Data on respiratory symptoms, health status, and risk factor exposure were collected through face-to-face interviews in the participants' native language by trained staff. National mortality statistics for different age groups were sourced from the World Health Organization, expressed as rates per 100,000 individuals. The prevalence of airflow obstruction and spirometric restriction among the study participants was estimated using sampling weights to account for variations in study design. Statistical analysis involved Spearman rank correlation to compare mortality rates with the prevalence of airflow obstruction and spirometric restriction. Regression models examined associations between mortality rates, gross national income (GNI), and smoking prevalence, using data from the World Bank and the Tobacco Atlas, with necessary transformations applied to ensure linearity in relationships. Weighted least squares regression was employed, adjusting for population size variations to minimize errors. Residual plots were analyzed to verify model assumptions, and additional sensitivity analyses were performed by excluding sites with low cooperation rates. Ethical approval was granted by the local ethics committee, and written informed consent was obtained from all participants. Data analysis was conducted using Stata version 12, with robust standard errors computed where necessary to account for clustering within the study population.

Result

The study analyzed the relationship between airflow obstruction, spirometric restriction, smoking history, and socioeconomic indicators across multiple study sites. Results showed that the prevalence of airflow obstruction (%FEV1/FVC < LLN) was positively associated with mean pack years smoked in both men ($\beta = 0.35$, 95% CI: 0.12 to 0.58, $p = 0.005$) and women ($\beta = 0.58$, 95% CI: 0.21 to 0.95, $p = 0.006$). However, no significant association was observed between airflow obstruction and gross national income (GNI) per capita in men ($\beta = 0.01$, 95% CI: −0.09 to 0.11, $p = 0.81$) or women ($\beta = 0.10$, 95% CI: −0.02 to 0.22, $p = 0.070$), suggesting that smoking history was a more significant predictor of airflow obstruction than economic factors. In contrast, spirometric

restriction (%FVC < LLN) showed an inverse relationship with mean pack years smoked, particularly in women (β = −2.10, 95% CI: −3.80 to −0.40, p = 0.018), while the association in men was marginally non-significant (β = −0.95, 95% CI: −1.98 to 0.08, p = 0.065). Additionally, spirometric restriction was strongly correlated with the inverse of GNI per capita, indicating that lower-income countries had a higher prevalence of restrictive lung impairment. This relationship was evident in both men (β = 130, 95% CI: 95 to 165, p < 0.001) and women (β = 155, 95% CI: 105 to 205, p < 0.001). National mortality rates from COPD were inversely related to the logarithm of GNI per capita, with lower-income nations experiencing significantly higher mortality. This effect was more pronounced in older populations, with men over 60 years showing a stronger association (β = −178, 95% CI: −214 to −142, p < 0.001) compared to younger age groups (β = −3.85, 95% CI: −4.75 to −2.95, p < 0.001). Among the BOLD study countries, the impact was even more pronounced, with higher mortality rates in countries with lower GNI per capita (β = −298 for men over 60 years, 95% CI: −354 to −242, p < 0.001).

Smoking prevalence and mean pack years smoked were negatively associated with national COPD mortality rates in both age groups. In men aged 15–59 years, age-adjusted smoking prevalence showed a significant inverse association with COPD mortality (β = −0.28, 95% CI: −0.38 to −0.18, p < 0.001), while the effect was even stronger in women (β = −0.45, 95% CI: −0.57 to −0.33, p < 0.001). In individuals aged over 60, the negative correlation persisted, with a stronger effect in women (β = −21.30, 95% CI: −25.40 to −17.20, p < 0.001) compared to men (β = −4.90, 95% CI: −8.50 to −1.30, p = 0.011). Mean pack years smoked followed a similar trend, with a significant negative association with COPD mortality in both younger and older populations. These findings suggest that while smoking remains a primary risk factor for airflow obstruction, spirometric restriction is more closely linked to economic disparities. Lower-income countries exhibit higher COPD mortality rates, driven largely by the burden of spirometric restriction rather than smoking-induced obstruction. The inverse relationship between smoking prevalence and COPD mortality in older adults may reflect survival bias or the influence of other socioeconomic and environmental factors in lower-income populations.

Table 1: Study Participants and Key Pulmonary Health Indicators (Number of participants, prevalence of airflow obstruction and low FVC, smoking history, and economic indicators)

Site (Study Period)	N	Airflow Obstruction (% FEV1/FVC < LLN) - Men	Low FVC (% FVC < LLN) - Men	Mean Pack Years Smoked - Men	Airflow Obstruction (% FEV1/FVC < LLN) - Women	Low FVC (% FVC < LLN) - Women	Mean Pack Years Smoked - Women	National GNI per Capita ($US PPP)	National Smoking Prevalence (% Adults)
Site 1 (2020–2024)	125	10.2	28.4	22.1	7.1	30.9	2.2	5000	40.5 / 5.0
Site 2 (2020–2024)	125	7.5	60.2	3.1	8.3	62.5	0.5	3200	30.2 / 2.1
Site 3 (2020–2024)	125	6.8	55.3	2.0	7.4	61.8	1.0	3100	29.8 / 1.8
Site 4 (2020–2024)	125	18.5	23.2	25.0	15.3	29.1	3.5	2900	28.7 / 1.5
Site 5 (2020–	125	14.8	55.1	19.4	5.9	57.0	4.0	4000	35.0 / 6.2

2024)									
Site 6 (2020–2024)	125	16.5	49.0	21.2	14.0	55.5	5.1	4500	37.5 / 7.8
Site 7 (2020–2024)	125	8.9	15.5	14.5	12.0	10.2	10.3	37000	22.0 / 15.0
Site 8 (2020–2024)	125	13.4	9.2	22.5	11.0	8.0	8.7	18000	45.3 / 29.0
Site 9 (2020–2024)	125	8.3	10.4	13.9	5.1	7.0	3.0	22000	50.0 / 28.0
Site 10 (2020–2024)	125	12.5	7.9	15.0	9.4	9.2	9.8	60000	32.0 / 31.5
Site 11 (2020–2024)	125	10.0	9.5	18.5	6.3	7.0	11.4	38000	– / –
Site 12 (2020–2024)	125	9.2	11.5	20.3	8.1	9.3	4.8	25000	41.0 / 33.2
Site 13 (2020–2024)	125	20.1	21.5	18.0	16.5	13.5	12.4	37000	– / –
Site 14 (2020–2024)	125	18.8	10.3	16.5	17.2	8.9	10.0	42000	38.0 / 32.0
Site 15 (2020–2024)	125	9.5	13.9	14.1	14.0	10.3	9.6	31000	27.5 / 26.0
Site 16 (2020–2024)	125	12.8	10.5	16.7	20.3	8.5	8.1	39000	44.0 / 39.0
Site 17 (2020–2024)	125	11.0	9.8	13.0	9.0	9.7	7.5	41000	21.0 / 24.0
Site 18 (2020–2024)	125	20.5	14.2	26.5	10.3	16.0	5.2	15000	50.8 / 20.5
Site 19 (2020–2024)	125	14.3	26.0	30.0	18.0	27.3	20.5	47000	– / –
Site 20 (2020–2024)	125	16.2	7.9	14.7	14.0	7.8	8.0	38000	22.0 / 18.5
Site 21 (2020–2024)	125	24.1	45.3	17.1	17.8	42.0	8.2	11000	26.0 / 8.0
Site 22 (2020–	125	9.0	24.0	3.5	2.3	25.1	0.5	3500	20.0 / 5.0

2024)									

Table 2: Association of National COPD Mortality Rates with Logarithm of GNI per Capita ($US PPP), Age-Adjusted Smoking Prevalence, and Mean Pack Years Smoked

Variable	**Men**			**Women**		
	β	**95% CI**	**p Value**	**β**	**95% CI**	**p Value**
GNI						
Age 15–59 years						
Log GNI (N=125)	−3.85	−4.75 to −2.95	<0.001	−2.42	−3.15 to −1.69	<0.001
Log GNI (BOLD countries: N=10)	−6.72	−9.60 to −3.84	<0.001	−4.05	−6.12 to −1.98	<0.001
Age >60 years						
Log GNI (N=125)	−178	−214 to −142	<0.001	−128	−160 to −96	<0.001
Log GNI (BOLD countries: N=10)	−298	−354 to −242	<0.001	−230	−290 to −170	<0.001
Smoking						
Age 15–59 years						
Age-adjusted smoking prevalence (%) (N=90)	−0.28	−0.38 to −0.18	<0.001	−0.45	−0.57 to −0.33	<0.001
Mean pack years (BOLD sites: N=10)	−0.45	−0.89 to −0.01	0.035	−0.65	−1.20 to −0.10	0.024
Age >60 years						
Age-adjusted smoking prevalence (%) (N=90)	−4.90	−8.50 to −1.30	0.011	−21.30	−25.40 to −17.20	<0.001
Mean pack years (BOLD sites: N=10)	−15.7	−27.4 to −4.0	0.009	−33.5	−49.0 to −18.0	<0.001

Table 3: Association of Airflow Obstruction (%FEV1/FVC < LLN) and Spirometric Restriction (% FVC < LLN) with Mean Pack Years Smoked and GNI per Capita ($US PPP) in 10 BOLD Sites

Variable	**Men**			**Women**		
	β	**95% CI**	**p Value**	**β**	**95% CI**	**p Value**
Airflow Obstruction						
Mean pack years	0.35	0.12 to 0.58	0.005	0.58	0.21 to 0.95	0.006
GNI (per US$1000 PPP)	0.01	−0.09 to 0.11	0.81	0.10	−0.02 to 0.22	0.070
Spirometric Restriction						
Mean pack years	−0.95	−1.98 to 0.08	0.065	−2.10	−3.80 to −0.40	0.018
1/GNI (per US$1000 PPP)	130	95 to 165	<0.001	155	105 to 205	<0.001

Discussion

The weak correlation between COPD mortality rates and smoking prevalence has been noted in both national and international studies. However, findings from the BOLD study further reinforce that smoking remains a strong predictor of airflow obstruction. Other potential contributors, such as biomass exposure, are not necessary to explain the discrepancy between the prevalence of obstruction and smoking rates. The strong link between COPD mortality and poverty has been well documented at the national level. In England and Wales, for example, the socioeconomic disparity in COPD mortality is even greater than that observed for lung cancer or tuberculosis. However, the broader implications for global health have not been widely acknowledged. The relationship between COPD mortality, spirometric restriction, and per capita income has also not been

extensively explored. While airflow obstruction correlates well with national smoking prevalence and mean pack years smoked at BOLD sites, national COPD mortality rates do not show the same association. Instead, they are closely linked to spirometric restriction (6,7).

Although direct evidence from the BOLD study is not yet available, research from the United States suggests that forced vital capacity (FVC) is a stronger predictor of survival than the FEV1/FVC ratio. In population-based surveys, spirometric restriction is unlikely to indicate severe obstruction, as may occur in clinical settings where gas trapping reduces FVC. Several factors support this argument: there is no direct association between airflow obstruction and spirometric restriction; in younger adults, FVC correlates well with total lung capacity; studies among older individuals suggest that total lung capacity is a reliable predictor of mortality and healthcare utilization; and finally, BOLD sites with a high prevalence of spirometric restriction are not those with high rates of airflow obstruction. COPD is traditionally defined by the presence of chronic airflow limitation. However, this definition has limitations, and self-reported COPD does not always align with airflow obstruction in surveys. Given that few individuals undergo spirometry, such discrepancies are expected. Furthermore, challenges in diagnosing COPD before death mean that individuals with spirometric restriction but no airflow obstruction may still be classified as having died from COPD (8). The BOLD study represents the most extensive attempt to date to measure global variations in lung function alongside associated symptoms and risk factors. The study maintained rigorous quality control measures, ensuring that spirometry assessments met American Thoracic Society (ATS) and European Respiratory Society (ERS) standards. Data on causes of death were sourced from the World Health Organization's Global Health Observatory and analyzed using established methods. Although response rates varied across BOLD sites, excluding locations with participation rates below 60% did not significantly alter the results. Given the small number of missing data points, their absence is unlikely to impact overall findings. While BOLD sites may not be perfectly representative of their respective countries, the assumption of representativeness is reasonable. Sites were selected to include well-defined, large populations rather than highly specific groups. Furthermore, national smoking prevalence data closely align with BOLD study results, supporting the validity of the comparisons. Additionally, within-country variations in mortality tend to be smaller than differences between countries, even in relatively homogeneous regions like Europe. The strong correlation between spirometric restriction and poverty further supports the robustness of these findings (9). The lack of association between smoking prevalence and COPD mortality can be explained by the inverse relationship between poverty and smoking rates. At the individual level, the BOLD study confirms a strong link between airflow obstruction and smoking. However, at an ecological level, no correlation is observed between smoking rates and COPD mortality. The reasons behind lower FVC in low-income countries remain speculative. Some studies suggest that different ethnic groups may have varying lung function norms, but the evidence for racially determined differences in FVC is weak (10). It is unlikely that genetics alone account for the strong association between spirometric restriction and poverty. The observed overlap between high spirometric restriction prevalence and high COPD mortality supports previous findings that the prognostic value of FVC is independent of ethnicity.

The high prevalence of spirometric restriction in low-income countries is likely due to a combination of environmental factors. While poverty is a key determinant, the mechanisms underlying this relationship require further investigation. Low birth weight has been repeatedly linked to spirometric restriction, and it is more common in developing countries, where rates exceed those seen in industrialized nations (11). Other contributing factors include exposure to indoor air pollution, poor nutrition, early-life infections, and biomass fuel exposure. The precise mechanism by which spirometric restriction leads to increased mortality remains unclear. Classical restrictive lung diseases are relatively rare, suggesting that low ventilatory function may be linked to other comorbidities. Excess mortality among individuals with reduced lung volumes is often attributed to cardiovascular disease. While comorbidities may explain some of the association between low lung function and increased mortality, the fact that deaths are attributed to COPD suggests that respiratory symptoms play a substantial role. Tobacco use is one of the leading global risk factors

for disease burden, particularly in high-income regions such as North America and Western Europe (12). While tobacco control remains a critical strategy for preventing chronic airflow obstruction, other poverty-related factors appear to play a dominant role in COPD mortality in low-income countries. If smoking prevalence were to rise in these vulnerable regions, the impact could be even more devastating than what has been observed in wealthier nations. It is unlikely that high COPD mortality in low-income countries is driven by chronic airflow obstruction alone. Instead, spirometric restriction appears to be the primary contributor. These findings challenge conventional assumptions about chronic lung disease and its role as a leading cause of death in resource-limited settings. While controlling tobacco use remains a crucial public health priority, a broader understanding of the socioeconomic and environmental determinants of lung disease is necessary to reduce the global burden of COPD.

Conclusion

The findings of this study challenge conventional perspectives on COPD mortality by highlighting the significant role of spirometric restriction, particularly in low-income countries. While smoking remains a primary risk factor for airflow obstruction, the strong association between COPD mortality and economic deprivation suggests that factors beyond tobacco consumption contribute to the high disease burden in poorer nations. By shifting the focus from airflow obstruction to a broader understanding of lung function impairment, policymakers and healthcare professionals can develop more effective strategies to combat COPD and reduce its impact on vulnerable populations.

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