INDONESIAN HEALTH JOURNAL
https://ihj.rivierapublishing.id/index.php/rp
Volume 5 Number 2, June 2026
P-ISSN: 2963-3044
E-ISSN: 2963-3036

Association of Brinkman Index with Airflow Limitation in Active Smokers Using Portable Spirometry at Saketa Primary Health Care Center

Alicia Thessalonica Nata[1*], Susaniwati[2]
Saketa Primary Health Care Center, South Halmahera, Indonesia[1]
Universitas Ciputra, Indonesia, Indonesia[2]
Email: aliciaecha@gmail.com[1*]

Keywords
FEV1; Spirometry; Brinkman Index

Abstract

Tobacco-related diseases account for more than seven million deaths globally each year. In Indonesia, approximately 295,043 deaths in 2025 were attributed to tobacco use. Identifying reliable parameters for early detection of pulmonary impairment in smokers, particularly those who are still asymptomatic, is therefore essential. This research aimed to evaluate the association between Brinkman Index score and FEV_1% predicted (measured using portable spirometry) among active smokers at Saketa Primary Health Care Center. This cross-sectional study included 40 male active smokers aged ≥35 years at Saketa Primary Health Care Center, South Halmahera, selected using a consecutive sampling method. The Brinkman Index score was used as the independent variable, while FEV_1% predicted, measured using portable spirometry according to American Thoracic Society standards, was the dependent variable. Data were analysed using Spearman's correlation test. The mean smoking duration was 29.83 ± 8.85 years, with an average cigarette consumption of 17.50 ± 6.88 cigarettes per day. The mean FEV_1% predicted was 74.90 ± 5.91%. Analysis using Spearman's correlation showed a strong negative association between Brinkman Index score and FEV_1% predicted, which was statistically significant ($r = -0.771$; $p < 0.001$). Scatter plot analysis showed a coefficient of determination of $R^2 = 0.610$, indicating that higher Brinkman Index score values were associated with lower FEV_1% predicted values among active smokers.

INTRODUCTION

Tobacco use remains a significant global public health concern and is associated with considerable mortality, chronic morbidity, and long-term health consequences. More than seven million deaths worldwide each year are attributed to tobacco-related diseases (World Health Organization, 2025). In Indonesia, approximately 295,043 deaths in 2025 were caused by tobacco use (Drope & Hamill, 2025). Respiratory conditions associated with smoking include chronic obstructive pulmonary disease (COPD), lung malignancy, tuberculosis, and various respiratory tract infections (Perhimpunan Dokter Paru Indonesia, 2024). The global population of adult male tobacco users in 2024 was estimated at approximately 849 million (World Health Organization, 2025).

According to the 2025 Health Statistics Profile, the prevalence of tobacco cigarette use in Indonesia exceeds that of electronic cigarette use (Badan Pusat Statistik, 2025). Approximately 28.70% of the adult population in Indonesia are smokers. Smoking prevalence is higher among men (56%) than women (1.40%) (Drope & Hamill, 2025). Smoking prevalence is higher in rural areas (31.39%) compared to urban areas (26.86%) (Badan Pusat Statistik, 2025). In North Maluku Province, the smoking prevalence in 2025 reached 29.08% (Badan Pusat Statistik, 2025).

Lung function declines progressively, particularly after the age of 35 years, characterised by a gradual reduction in alveolar surface area, impaired mucociliary clearance, and alterations in lung elasticity (Schneider et al., 2021). Therefore, reliable parameters are needed for early detection of pulmonary impairment in smokers, especially among those who remain asymptomatic (Sukmawati & Amin, 2016). FEV_1% predicted, defined as forced expiratory volume in one second, is among the most widely used spirometry parameters for evaluating airflow limitation and pulmonary function impairment (David et al., 2025). In certain ventilatory disorders, airflow obstruction develops gradually, with FEV_1 declining more rapidly than forced vital capacity (FVC), such that the FEV_1/FVC ratio may remain within normal limits in the early stages (Stanojevic et al., 2022). Therefore, this study focused on early lung function decline by using FEV_1% predicted as the primary parameter for detecting early pulmonary impairment in active smokers.

Spirometry remains an essential method for evaluating smoking-related impairment in lung function, particularly in the early stages of airflow limitation. Nevertheless, access to spirometry remains limited in many primary healthcare facilities, especially in low- and middle-income countries (Rossaki et al., 2021). Conventional laboratory-based spirometry is generally expensive, bulky, and requires regular calibration as well as trained personnel. In contrast, portable spirometry offers several advantages, including lower cost, ease of use, and improved accessibility (Gao et al., 2025).

Hand-held spirometers have been widely adopted in clinical practice due to their demonstrated validity and reproducibility. These devices are practical, efficient, user-friendly, and relatively affordable, with performance reported to be comparable to that of conventional spirometers (Bora et al., 2025). The Contec™ hand-held spirometer is a portable electronic device equipped with a high-resolution LCD display and integrated software that enables reliable measurements without the need for prior calibration (Bora et al., 2025). In this study, lung function measurements were performed using the CONTEC SP10W portable spirometer, which was considered suitable for assessing lung function parameters, particularly FEV_1 (Vera-Serrano et al., 2025). This is particularly important in rural primary healthcare settings in Indonesia, where access to conventional laboratory-based spirometry and pulmonary function testing facilities remains limited.

Cigarette smoking among active smokers exerts a cumulative and progressive effect on lung function decline. Portable spirometry can support the early detection of pulmonary impairment in active smokers, particularly among individuals who remain asymptomatic, thereby facilitating timely smoking cessation interventions and more effective prevention of disease progression. However, evidence regarding the association between Brinkman Index and FEV_1% predicted measured using portable spirometry in rural primary healthcare settings in Indonesia remains limited. Therefore, this study was conducted to evaluate the association between the Brinkman Index and FEV_1% predicted, measured by portable spirometry, among active smokers at Saketa Primary Health Center.

This research provides both theoretical and practical benefits. Theoretically, this study contributes to the body of knowledge on the relationship between cumulative smoking exposure and early lung function decline, particularly by using the Brinkman Index as a simple yet reliable parameter for assessing smoking intensity. The findings reinforce the application of portable spirometry as a valid screening tool in resource-limited primary care settings, thereby enriching the literature on community-based pulmonary health assessment. Practically, the results of this study can assist primary care physicians and health workers at Saketa Primary Health Center and other similar facilities in identifying high-risk smokers who may already have asymptomatic airflow limitation. Early detection using the Brinkman Index and portable spirometry can facilitate timely smoking cessation interventions, prevent further lung function deterioration, and ultimately reduce the burden of smoking-related pulmonary diseases such as

COPD. Furthermore, this study provides evidence to support the integration of portable spirometry into routine health screening programmes for active smokers in rural primary healthcare settings in Indonesia.

METHOD

This research employed an analytic observational cross-sectional design and was conducted at Saketa Primary Health Care Center, South Halmahera, Indonesia, from December 2025 to January 2026. A total of 40 male active smokers aged ≥35 years who fulfilled the predefined inclusion and exclusion criteria were recruited using a consecutive sampling method.

The inclusion criteria comprised male active smokers aged ≥35 years who visited Saketa Primary Health Care Center during the study period, provided informed consent, and were capable of performing spirometry appropriately. Male participants were specifically selected because the prevalence of active smoking in Indonesia is substantially higher among men than women.

The exclusion criteria included female participants, individuals with a history of pulmonary diseases (asthma, active tuberculosis, pulmonary fibrosis, bronchiectasis, or lung cancer), cardiovascular diseases (heart failure or coronary artery disease), musculoskeletal or neurological disorders, recent acute respiratory infection within the past two weeks, inability to perform spirometry properly, or refusal to provide informed consent.

The independent variable was the Brinkman Index score, while the dependent variable was FEV1% predicted. The Brinkman Index score was calculated as the product of the number of cigarettes smoked per day and the duration of smoking (in years). Informed consent was obtained from all participants prior to data collection.

Forced expiratory volume in one second (FEV1) was measured using a CONTEC SP10W portable spirometer. The highest value obtained from three acceptable maneuvers was recorded. The measured FEV1 was then compared with predicted reference values based on Indonesian standard lung function values, adjusted for age and height, to obtain FEV1% predicted.

Pulmonary function assessment was conducted using the CONTEC SP10W portable spirometer, which has demonstrated excellent reliability with an inter-rater reliability coefficient of $r = 0.99$. The spirometry procedure followed the standards established by the American Thoracic Society. All measurements were conducted using a standardized protocol, including subject positioning, forced expiratory technique, duration of exhalation, and repeated maneuvers.

Data processing and statistical analysis were performed using IBM SPSS Statistics version 26. Descriptive statistics were applied to summarize participant characteristics. Data normality was evaluated using the Shapiro-Wilk test. Brinkman Index score demonstrated a non-normal distribution ($p = 0.005$), whereas FEV1% predicted was normally distributed ($p = 0.506$). Accordingly, the association between Brinkman Index score and FEV1% predicted was analyzed using Spearman's rank correlation test. Scatter plot analysis was additionally performed to illustrate the relationship between Brinkman Index score and FEV1% predicted.

Prior to the study, all participants received information regarding the study objectives, procedures, and potential benefits. After fully understanding the study protocol, all participants provided written informed consent before participation in the study and spirometry examination.

RESULTS AND DISCUSSION

Table 1 presents the baseline characteristics of the study participants. The mean age was 47.95 ± 8.21 years, ranging from 36 to 65 years. The mean smoking duration was 29.83 ± 8.85 years, ranging from 17 to 48 years, whilst the average cigarette consumption was 17.50 ± 6.88 cigarettes per day, ranging from 6 to 36 cigarettes per day. The mean FEV_1% predicted was 74.90% ± 5.91, ranging from 64% to 89%. The mean Brinkman Index score was 558.30 ± 308.50, with values ranging from 102 to 1152.

Table 2 presents the results of Spearman's rank correlation analysis, demonstrating a strong and statistically significant negative correlation between Brinkman Index score and FEV_1% predicted ($r = -0.771$; $p < 0.001$). Higher Brinkman Index scores were associated with lower FEV_1% predicted values among active smokers.

Figure 1 demonstrates a negative linear relationship between Brinkman Index score and FEV_1% predicted. Scatter plot analysis showed a coefficient of determination (R^2) of 0.610, indicating a substantial inverse association between Brinkman Index score and FEV_1% predicted.

This study was conducted to evaluate the association between Brinkman Index score and FEV_1% predicted among active smokers using portable spirometry at Saketa Primary Health Center. The findings demonstrated a strong and statistically significant inverse correlation between Brinkman Index score and FEV_1% predicted ($r = -0.771$; $p < 0.001$), suggesting that greater cumulative smoking exposure was associated with reduced lung function in active smokers. The relatively strong correlation identified in this study may have been related to the homogeneous study population, which consisted exclusively of male active smokers aged ≥35 years with substantial cumulative smoking exposure.

Scatter plot analysis further demonstrated a substantial inverse association between Brinkman Index score and FEV_1% predicted. However, lung function decline may also be affected by other factors, particularly age, environmental exposure, and comorbid conditions.

Cigarettes commonly used in Indonesia are primarily made from tobacco (Nicotiana tabacum) typically wrapped in paper and equipped with a filter. When burned, they produce smoke containing approximately 5,000 chemical compounds, many of which are carcinogenic and contribute to cardiovascular and chronic pulmonary diseases. Approximately 60% of inhaled smoke particles are deposited in the lungs, leading to structural alterations and impaired lung function.

Previous studies have shown that smoking exposure reduces pulmonary surfactant levels, resulting in progressive and cumulative lung tissue damage that contributes to the development of chronic obstructive pulmonary disease (COPD). The extent of this damage correlates positively with cumulative exposure (pack-years) and is associated with narrowing of both large and small airways. Early detection of smoking-related pulmonary impairment may improve the effectiveness of smoking cessation interventions. Furthermore, accelerated lung ageing due to exposure to toxic substances in cigarette smoke contributes to decreased lung elasticity and increased airway resistance.[6] Smoking-related lung damage develops gradually and often remains asymptomatic until significant functional decline occurs.

The present findings are consistent with previous studies reporting progressive decline in lung function among active smokers. The annual decline in FEV_1 tends to become more pronounced with increasing age. In addition, previous studies have demonstrated a linear relationship between cigarette consumption and the rate of FEV_1 decline, with an estimated

additional reduction of approximately 12.6 mL per year for each daily pack of cigarettes smoked by men (Xu et al., 1992). Another study reported that individuals smoking approximately 20 cigarettes per day experience an average decline in FEV_1 of 54 mL per year (Hussain et al., 2012). Consistent with these findings, Hussain et al. (2012) reported that 44 out of 50 male smokers had FEV_1% predicted values below 80%. Another study by Kumar et al. (2022) found that 72.04% of smokers exhibited impaired lung function, with significant reductions across all spirometry parameters compared to non-smokers (Kumar et al., 2022).

Celli et al. (2022) reported that smoking-related pulmonary impairment may develop gradually, with declining lung function occurring even when the FEV_1/FVC ratio remains within normal limits and respiratory symptoms are absent. This suggests that pathological processes and functional decline occur long before a formal diagnosis can be established (Celli et al., 2022). Huang et al. (2024) also reported that early impairment of lung function may be characterised by reduced FEV_1 despite a preserved FEV_1/FVC ratio, particularly amongst male active smokers, and may increase the risk of smoking-related pulmonary impairment and acute exacerbations within 4–5 years. Mild reductions in FEV_1% predicted may still return to normal, whereas more severe reductions may progress to advanced COPD (Huang et al., 2024).

Cigarette smoking contributes to chronic inflammation, fibrotic changes, and mucus hypersecretion in the small airways (diameter <2 mm), which may increase peripheral airway resistance. Early small airway abnormalities may be reflected by a decline in FEV_1 despite preservation of the FEV_1/FVC ratio (Zhang et al., 2025).

Approximately 50% of smokers experience an accelerated decline in FEV_1 over time and eventually develop chronic obstructive pulmonary disease (COPD). Although age is often considered a risk factor for COPD due to the natural decline in lung function, it remains unclear whether ageing acts as a direct causal factor or merely reflects the cumulative burden of risk exposures throughout life (Global Initiative for Chronic Obstructive Lung Disease, 2025).

FEV_1 represents the volume of air (in litres) forcibly exhaled during the first second following maximal inspiration. A reduction in FEV_1% predicted tends to occur earlier, reflecting initial impairment in airflow. Small airways are bronchioles with a diameter of less than 2 mm and without cartilaginous support, making them highly vulnerable to inhaled toxins and irritants. Because abnormalities in these airways are often difficult to detect clinically, they are commonly referred to as the "silent zone" (Zhou et al., 2025).

Early dysfunction of the small airways often occurs before the development of clinical symptoms and may already be reflected by a decline in FEV_1% predicted. Small airway dysfunction is associated with complex pathological processes, including chronic inflammation, mucus hypersecretion, epithelial–mesenchymal transition (EMT), fibrotic remodelling, microvascular changes, epithelial barrier dysfunction, and cellular senescence. The small airway epithelium functions as an important defence barrier against inhaled harmful particles and pathogens. Prolonged cigarette smoke exposure may impair mucociliary function, induce goblet cell hyperplasia, alter tight junction proteins, and subsequently disrupt mucociliary clearance and epithelial integrity (Zhou et al., 2025).

The decline in lung function amongst smokers is largely attributable to the toxic effects of cigarette smoke on both the airways and lung parenchyma. These exposures trigger chronic inflammation and oxidative stress, leading to ciliary damage, mucus gland and goblet cell hyperplasia, excessive mucus production, small airway obstruction, and alveolar destruction,

collectively contributing to impaired pulmonary function (Kumar et al., 2022). Approximately 60% of inhaled mainstream smoke particles are deposited in the lungs, resulting in structural and functional alterations of the lung parenchyma (Perhimpunan Dokter Paru Indonesia, 2024). In addition, epithelial injury caused by cigarette smoke may contribute to structural alterations of the small airways and progressive decline in lung function. Epigenetic mechanisms induced by cigarette smoke, including DNA methylation and histone modifications, may further contribute to chronic inflammation and airway remodelling associated with smoking-related pulmonary impairment (Wirawan et al., 2025).

These processes may progress to fibrotic remodelling through mechanisms such as EMT, resulting in airway wall thickening and luminal narrowing. In addition, mucus retention and mucus plugging further exacerbate airflow limitation. The lack of cartilaginous support also predisposes small airways to dynamic collapse during expiration, particularly under increased intrathoracic pressure. This combination of increased resistance and airway collapse predominantly affects early expiratory airflow, leading to an initial decline in FEV_1. In contrast, forced vital capacity (FVC) remains relatively preserved in the early stages, as total lung volume can still be expelled, albeit more slowly, resulting in a preserved FEV_1/FVC ratio (Zhou et al., 2025).

Previous studies have demonstrated a significant association between smoking intensity and the severity of smoking-related pulmonary impairment. Most individuals with chronic smoking-related airflow limitation have a history of substantial cumulative smoking exposure, commonly exceeding 10 pack-years. In addition, smoking-related lung function impairment has been reported more frequently amongst male smokers aged ≥40 years compared with females (Global Initiative for Chronic Obstructive Lung Disease, 2025).

As the first point of contact in the healthcare system, primary care physicians play a crucial role in supporting smoking cessation efforts. Through counselling, they can improve smoking cessation success rates and facilitate early detection of smokers, including those who are asymptomatic. Early intervention is crucial, as lung function decline begins before the onset of clinical symptoms; therefore, timely smoking cessation may improve prognosis and increase life expectancy (Kumar et al., 2022). Although portable spirometry may facilitate early screening in primary healthcare settings, abnormal findings should be confirmed using standard laboratory-based spirometry.

This study has several limitations, including its cross-sectional design, which precludes causal inference, a relatively small sample size, and the inclusion of only male participants, limiting generalisability. In addition, potential confounding factors, particularly age-related decline in lung function, were not controlled statistically and may have influenced the observed association between Brinkman Index score and FEV_1% predicted. Furthermore, smoking history was obtained through self-reporting and may therefore be susceptible to recall bias. Future longitudinal studies involving larger sample sizes and multivariable analyses are warranted to better evaluate the independent effect of smoking exposure on lung function decline.

CONCLUSION

A strong and statistically significant negative association was observed between Brinkman Index score and FEV1% predicted among active smokers aged ≥35 years at Saketa

Primary Health Center. Higher levels of smoking exposure, as measured by the Brinkman Index score, were associated with lower FEV1% predicted values. Scatter plot analysis demonstrated a substantial inverse association between Brinkman Index score and FEV1% predicted.

These findings emphasize the importance of smoking prevention and smoking cessation strategies in rural primary healthcare settings. Nevertheless, the cross-sectional nature of this study does not permit causal interpretation of the association between smoking exposure and lung function decline. Additionally, the relatively small sample size and the inclusion of only male participants may reduce the generalizability of the findings. Although portable spirometry may be useful as an initial screening tool in primary care settings, further evaluation using standard spirometry in accordance with American Thoracic Society guidelines remains necessary before confirming a diagnosis of obstructive lung disease.

REFERENCES

Badan Pusat Statistik. (2025). *Profil statistik kesehatan 2025*. Badan Pusat Statistik.

Bora, H., Jonnavithula, N., Geetha, S., Kumar, D. S., Lakkam, K., & Rao, N. (2025). Correlation between breath-holding time and hand-held portable Contec spirometer parameters in pre-operative pulmonary function assessment: A prospective observational study. *Journal of Clinical Sciences Research, 14*(3), 161–166.

Celli, B., Fabbri, L., Criner, G., Martinez, F. J., Mannino, D., Vogelmeier, C., et al. (2022). Definition and nomenclature of chronic obstructive pulmonary disease: Time for its revision. *American Journal of Respiratory and Critical Care Medicine, 206*(11), 1317–1325.

David, S., Goldin, J., & Edwards, W. C. (2025). Forced expiratory volume. In *StatPearls*. StatPearls Publishing.

Drope, J., & Hamill, S. (2025). *The Tobacco Atlas: Country profile—Indonesia*. Vital Strategies.

Global Initiative for Chronic Obstructive Lung Disease. (2025). *Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: 2025 report*.

Gao, Y., Liang, B., Su, X., Rao, W., Cheng, H., Fan, C., et al. (2025). Reliability and usability of a portable spirometer compared to a laboratory spirometer. *BMC Pulmonary Medicine, 25*, 228.

Huang, J., Li, W., Sun, Y., Huang, Z., Cong, R., Yu, C., et al. (2024). Preserved ratio impaired spirometry (PRISm): A global epidemiological overview, radiographic characteristics, comorbid associations, and differentiation from chronic obstructive pulmonary disease. *International Journal of Chronic Obstructive Pulmonary Disease, 19*, 753–764.

Hussain, A., Abdullah, I., Nagra, M. H., Masood, A., Sarfaraz, M., & Qureshi, S. (2012). Comparison of forced expiratory volume in one second (FEV1) between smoker and non-smoker doctors. *Annals of Punjab Medical College, 6*(2), 131–135.

Kumar, N., Chawla, G., Kansal, A. P., Deokar, K., Niwas, R., Abrol, N., et al. (2022). Air flow limitation in smokers: A cause of concern. *Journal of Family Medicine and Primary Care, 11*(11), 6807–6811.

Perhimpunan Dokter Paru Indonesia. (2024). *Pedoman diagnosis dan penatalaksanaan*

berhenti merokok di Indonesia. PDPI.

Rossaki, F. M., Hurst, J. R., van Gemert, F., Kirenga, B. J., Williams, S., Khoo, E. M., Tsiligianni, I., Tabyshova, A., & van Boven, J. F. M. (2021). Strategies for the prevention, diagnosis and treatment of COPD in low- and middle-income countries: The importance of primary care. *Expert Review of Respiratory Medicine, 15*(12), 1563–1577.

Schneider, J. L., Rowe, J. H., Garcia-de-Alba, C., Kim, C. F., Sharpe, A. H., & Haigis, M. C. (2021). The aging lung: Physiology, disease, and immunity. *Cell, 184*(8), 1990–2019.

Stanojevic, S., Kaminsky, D. A., Miller, M. R., Thompson, B., Aliverti, A., Barjaktarevic, I., et al. (2022). ERS/ATS technical standard on interpretive strategies for routine lung function tests. *European Respiratory Journal, 60*(1).

Sukmawati, A., & Amin, M. (2016). Perbandingan nilai forced expiratory flow (FEF)25–75% pada perokok dan bukan perokok. *Jurnal Respirasi Indonesia, 36*(3), 167–174.

Vera-Serrano, F. J., Vinolo-Gil, M. J., Seguín, L. M. F., & Díaz-Mancha, J. A. (2025). Effects of diaphragmatic manual therapy on respiratory function in patients with non-specific low back pain: A randomized controlled trial. *Respiratory Medicine*, 108394.

World Health Organization. (2025a). *WHO global report on trends in prevalence of tobacco use 2000–2024 and projections 2025–2030*. World Health Organization.

World Health Organization. (2025b). *WHO report on the global tobacco epidemic, 2025: Warning about the dangers of tobacco*. World Health Organization.

Wirawan, A., Kinasih, T., Imaniar, R., Baskoro, H., Antariksa, B., & Matsumoto, N. (2025). Exploring epigenetic landscapes in COPD: Therapeutic implications and recent insights. *Respiratory Science, 5*(2), 126–140.

Xu, X., Dockery, D. W., Ware, J. H., Speizer, F. E., & Ferris, B. G. (1992). Effects of cigarette smoking on rate of loss of pulmonary function in adults: A longitudinal assessment. *American Review of Respiratory Disease, 146*(5 Pt 1), 1345–1348.

Zhang, X., Chen, T., Zhang, G., Du, X., & Xu, R. (2025). Causal association between cigarette smoking and the prevalence of preserved ratio impaired spirometry (PRISm), and the progression risk factors of PRISm: A study based on Mendelian randomization and meta-analysis. *Tobacco Induced Diseases, 23*, 1–11.

Zhou, R., Wang, H., Zhang, Y., & Mai, J. (2025). Small airway disease as a key factor in COPD: New perspectives and insights. *Frontiers in Medicine, 12*, 1648612.