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Original Article

Analysis of Pulmonary Function between E-Cigarette Users and Non-Smokers Aged 20–30 Years in Jakarta

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Abstract

Background: This study aimed to compare pulmonary function between e-cigarette users and non-smokers aged 20–30 years in Jakarta.

Methods: A cross-sectional study was carried out between May 2023 and May 2024 at SMC Clinic Jakarta, Ibnusina Hospital Jakarta, and Naura Medika Clinic Depok. The sample consisted of 65 individuals who used e-cigarettes and 63 individuals who did not smoke. Spirometry was employed to evaluate pulmonary function by measuring forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), and the FEV_1/FVC ratio. The data were analyzed using independent t-tests using IBM SPSS software version 25.0.

Results: The study revealed substantial disparities in pulmonary function between individuals who use e-cigarettes and those who do not smoke. Individuals who use e-cigarettes had significantly reduced FEV_1 at 3.02±0.50 L and FVC at 4.00±0.47 L, in comparison to non-smokers (FEV_1=3.51±0.57 L; FVC=4.57±0.50 L). E-cigarette users exhibited a considerably lower FEV_1/FVC ratio (74.86±5.55) compared to non-smokers (79.29±5.11), suggesting a higher occurrence of obstructive airway diseases.

Conclusion: Young adults aged 20-30 years in Jakarta who use e-cigarettes experience a decrease in pulmonary function. The results emphasize the possible respiratory hazards associated with the use of e-cigarettes and emphasize the necessity for greater awareness and regulatory actions to tackle these hazards.

Keywords: e-cigarette, pulmonary function, respiratory health, spirometry, young adults

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INTRODUCTION

Over the past several years, the prevalence of e-cigarettes, also referred to as vaping, has experienced a significant rise, especially among the younger demographic.[1] E-cigarettes are frequently promoted as a less hazardous substitute for conventional tobacco smoking and as an efficacious means of quitting smoking.[2]

Nevertheless, the health consequences of using e-cigarettes for an extended time remain incompletely comprehended, and there is a continuing dispute among scientists regarding their safety.[2] This study seeks to enhance the ongoing discourse by examining pulmonary function in individuals aged 20-30 years who use e-cigarettes, as compared to non-smokers, in Jakarta, a prominent urban hub in Indonesia.

E-cigarettes were initially introduced to the market in the early 2000s and have subsequently garnered significant global popularity.[3] These devices function by applying heat to a liquid (sometimes called e-liquid or vape juice) that contains nicotine, flavorings, and other substances.[4] The resulting aerosol is then inhaled. E-cigarettes differ from ordinary cigarettes in that they do not combust tobacco, hence eliminating the generation of numerous toxic by-products of combustion.[5] This disparity has resulted in the assumption that e-cigarettes are a more secure alternative for nicotine ingestion.[3]

The popularity of e-cigarettes, particularly among younger populations, has been further enhanced by marketing efforts and the introduction of a diverse range of attractive flavors. Recent polls indicate that a substantial proportion of young individuals have experimented with vaping, and a considerable number have subsequently become regular users.[3] Although e-cigarettes are widely used, there is still significant ambiguity about the potential long-term impact on respiratory health.

Although e-cigarettes are typically seen as less detrimental than conventional cigarettes, they nonetheless pose dangers. The aerosol emitted by e-cigarettes contains nicotine, a highly addictive stimulant, along with other potentially hazardous compounds such as heavy metals, volatile organic compounds, and flavoring ingredients that can be dangerous when breathed.[6,7]

Multiple studies have demonstrated that the use of e-cigarettes can result in respiratory problems.[8] Immediate consequences documented encompass inflammation of the throat and airways, coughing, and difficulty breathing. Of greater worry are the potential long-term effects on lung health, which are yet completely unknown.[9,10]

Recent findings indicate that the use of e-cigarettes might be a contributing factor to the development of long-term respiratory disorders, including asthma and chronic obstructive pulmonary disease (COPD).[9] Moreover, there are apprehensions over the possibility of e-cigarettes acting as a conduit to conventional smoking, especially among young individuals.[7,10]

Pulmonary function is a key marker of lung health, typically measured by spirometry.[11] Important variables assessed in spirometry include forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), and the FEV_1/FVC ratio. FEV1 quantifies the quantity of air that an individual can forcefully expel during a single second, whereas FVC denotes the total amount of air exhaled during a compelled breath. The FEV_1/FVC ratio is utilized for the diagnosis of obstructive and restrictive airway diseases.[12]

Prior studies have confirmed that smoking conventional cigarettes results in a deterioration of pulmonary function, characterized by decreased FEV_1, FVC, and a diminished FEV_1/FVC ratio.[13] Nevertheless, the effect of e-cigarettes on these factors remains uncertain. Several studies have indicated a decrease in pulmonary function among those who use e-cigarettes. However, other investigations have observed no notable disparities when compared to individuals who do not smoke.[14] These differences highlight the need for further research.

Jakarta, the capital city of Indonesia, is an ideal location for this study because of its dense population and the increasing frequency of e-cigarette usage among young adults.[11] Indonesia possesses one of the highest smoking prevalence rates globally, and the emergence of e-cigarettes has brought a fresh aspect to the nation's public health scenario.[15] It is essential to comprehend the impact of e-cigarette usage on pulmonary function in this particular situation to formulate efficient public health initiatives and laws.

This study aimed to compare pulmonary function between e-cigarette users and non-smokers aged 20–30 in Jakarta. This study intends to get insights into the initial impact of e-cigarette usage on respiratory health by specifically targeting a young adult group. The study will specifically assess and analyze the FEV_1, FVC, and the ratio of FEV_1 to FVC to discover if there are any significant variations between the two groups.

METHODS

This study was conducted using a cross-sectional method to compare pulmonary function between e-cigarette users and non-smokers aged 20-30 years at the SMC Clinic Jakarta. The study period was from May 2023 to May 2024. The inclusion criteria for this study were young adults aged 20-30 years who were either e-cigarette users or non-smokers.

Participants with incomplete medical records, incomplete smoking history, those who refused or were unable to take part in this study were excluded.

Participants were recruited through purposive sampling at RS Ibnusina, SMC Clinic, and Naura Medika Clinic. A total of 128 participants met the inclusion criteria and were willing to participate in the study. Among them, 65 were e-cigarette users and 63 were non-smokers. Each subject signed the informed consent.

Participants categorized as e-cigarette users in this study were defined based on their duration and frequency of e-cigarette usage, as reported through structured questionnaires. Duration was categorized into three groups: short-term (<1 year), medium-term (1-3 years), and long-term (>3 years) users. Frequency of usage was classified as infrequent (≤3 days/week), moderate (4-6 days/week), and frequent (daily use).

Participants underwent spirometry tests to measure pulmonary function, including FEV_1, FVC, and the FEV_1/FVC ratio. Each participant performed three spirometry trials and the best result was used for analysis. Spirometry was conducted under standardized conditions to ensure accuracy and reliability. Data were collected through questionnaires that included demographic information (age, gender) and details of e-cigarette use (duration and frequency). Spirometry data were recorded and analyzed to assess pulmonary function.

The data were processed and analyzed using IBM SPSS software version 25.0 with a 95% confidence level. Descriptive statistics were used to summarize the demographic characteristics and pulmonary function parameters of the two groups. An independent t-test was used to compare pulmonary function parameters (FEV_1, FVC, FEV_1/FVC) between e-cigarette users and non-smokers to determine if there were significant differences between the groups. The value of $P<0.05$ was considered statistically significant.

RESULTS

A total of 128 participants were included in the study, consisting of 65 e-cigarette users and 63 non-smokers. The mean age of e-cigarette users was 24.83±3.13 years, while that of non-smokers was 24.33±3.10 years. The gender distribution showed a predominance of males in the e-cigarette group (40 males and 25 females), whereas the non-smoker group comprised 29 males and 34 females (Table 1).

Table 1. Demographic Characteristic

Characteristic	E-Cigarette Users (n=65)	Non-Smokers (n=63)
Age (mean±SD)	24.83±3.13	24.33±3.10
Gender		
Male	40	29
Female	25	34

Analysis of pulmonary function among e-cigarette users revealed a dose-dependent relationship between duration and frequency of usage and pulmonary function decline. Long-term users (>3 years) had significantly lower mean FEV_1 (2.81±0.42 L) and FVC (3.80±0.44 L) compared to short-term users (<1 year; FEV_1=3.20±0.51 L; FVC=4.15±0.48 L), with $P<0.01$. Similarly, frequent daily users exhibited reduced pulmonary function compared to infrequent users ($P<0.05$) (Table 2).

Table 2. Pulmonary Function by Duration and Frequency of e-cigarette Use

Category	FEV_1 (L)	FVC (L)	FEV_1/FVC (%)
Duration			
Short-term (<1 yr)	3.20±0.51	4.15±0.48	77.1±5.4
Medium-term (1–3 yr)	3.04±0.47	4.00±0.46	75.0±5.2
Long-term (>3 yr)	2.81±0.42	3.80±0.44	73.0±4.7
Frequency			
Infrequent (≤3 d/wk)	3.17±0.52	4.11±0.50	76.4±5.6
Moderate (4–6 d/wk)	3.03±0.48	3.95±0.47	74.8±5.1
Frequent (d)	2.89±0.46	3.91±0.45	73.2±4.8

Significant differences were observed in spirometry parameters between e-cigarette users and non-smokers (Table 3). E-cigarette users demonstrated significantly lower FEV_1 (3.02±0.50 L vs 3.51±0.57 L), FVC (4.00±0.47 L vs 4.57±0.50 L), and FEV_1/FVC ratio (74.86±5.55% vs 79.29±5.11%), with all comparisons yielding $P<0.001$.

Table 3. Pulmonary Function Parameters

Parameter	E-Cigarette Users	Non-Smokers	t-statistic	*P*
FEV_1	3.02±0.50	3.51±0.57	–5.22	<0.001
FVC	4.00±0.47	4.57±0.50	–6.58	<0.001
FEV_1/FVC	74.86±5.55	79.29±5.11	–4.70	<0.001

The study revealed a statistically significant decrease in the average FEV_1 among e-cigarette users compared to non-smokers. More precisely, the average FEV_1 for individuals who use e-cigarettes was 3.02±0.50 L, while for individuals who do not smoke, it was 3.51±0.57 L. An independent t-test was conducted to assess the difference in means. The t-statistic obtained was -5.22, with *P*<0.001. The highly significant value of *P* suggests a robust statistical difference between the two groups.

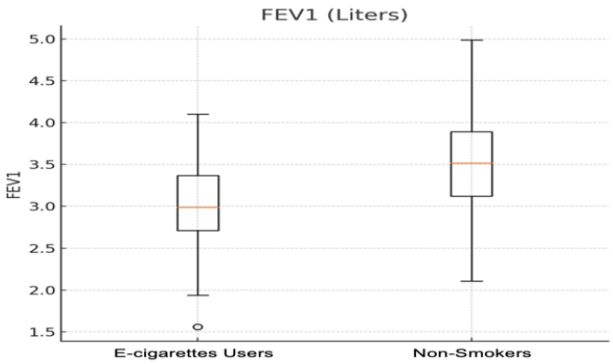

Figure 1. Comparison of FEV_1 Between e-cigarette users and Non-Smokers

The average FVC for individuals who use e-cigarettes in this study was 4.00±0.47 L, which was notably lower than the FVC of 4.57±0.50 L reported in individuals who do not smoke. The observed difference was statistically significant, as indicated by a t-statistic of -6.58 and *P*<0.001.

The average FEV_1/FVC ratio for individuals who use e-cigarettes was 74.86±5.55, while it was 79.29±5.11 for individuals who do not smoke. The observed difference was statistically significant, as indicated by a t-statistic of -4.70 and *P*<0.001. E-cigarette users exhibit a lower FEV_1/FVC ratio, indicating a greater occurrence of obstructive airway disorders, which are characterized by diminished airflow and challenges in exhaling. These findings indicate that the use of e-cigarettes may play a role in the emergence of illnesses such as COPD and asthma.

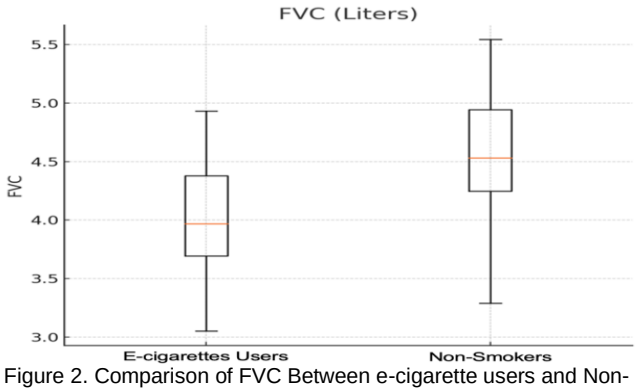

Figure 2. Comparison of FVC Between e-cigarette users and Non-Smokers

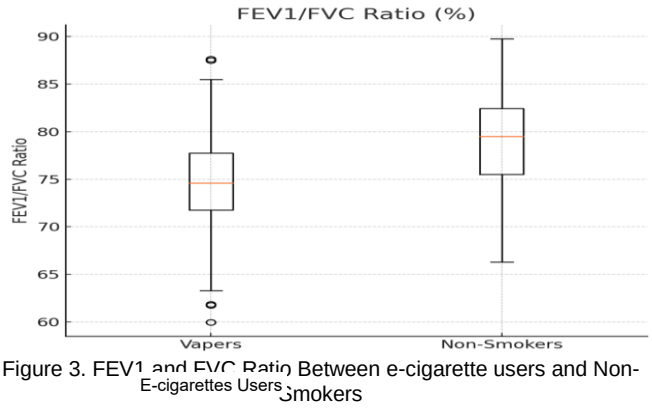

Figure 3. FEV1 and FVC Ratio Between e-cigarette users and Non-Smokers

DISCUSSION

FEV_1 is a crucial metric for assessing pulmonary function, which precisely measures the amount of air an individual can forcefully exhale during a duration of one second. It is commonly employed to diagnose and track respiratory diseases.[12] The average FEV_1 for individuals who use e-cigarettes was significantly lower (3.02±0.50 L) in comparison to individuals who do not smoke (3.51±0.57 L). The reduced FEV_1 observed in e-cigarette users indicates that these individuals may have impaired pulmonary function, possibly as a result of inhaling compounds present in e-cigarette aerosols. These substances can induce inflammation and harm the respiratory system.

The t-statistic for FEV_1 yielded a value of -5.22, while the *P*<0.001. These results indicate a substantial and statistically significant difference between the two groups. This discovery is consistent with prior studies

indicating that the use of e-cigarettes can result in a decline in pulmonary function.[16] This decline is attributed to the inhalation of dangerous compounds found in the vapor, including nicotine, propylene glycol, and various flavorings. These substances have the potential to induce inflammation and harm to the airways.[17]

The t-statistic value for FVC is -6.58 with $P<0.001$. The diminished FVC observed in individuals who use e-cigarettes indicates that their lung capacity is damaged, likely as a result of prolonged exposure to e-cigarette aerosols. This exposure may cause inflammation, tissue harm, and hinder lung expansion and contraction.

The FEV_1/FVC ratio is a calculated measurement that offers vital information about the existence of obstructive or restrictive lung disorders. The calculation involves dividing the FEV_1 by the FVC and expressing the result as a percentage.[18] In persons who are in good health, this ratio is generally elevated, which suggests that there is a smooth and effective movement of air through the respiratory passages.

The notable disparities in pulmonary function indicators between those who use e-cigarettes and those who do not smoke underscore the possible negative impacts of e-cigarette usage on respiratory well-being. The diminished FEV_1 and FVC observed in individuals who use e-cigarettes indicate a weakened pulmonary function, potentially resulting in chronic respiratory problems. E-cigarette users with a lower FEV_1/FVC ratio are more likely to have obstructive airway problems, potentially leading to chronic respiratory disorders.

The results of this study align with prior research that has documented the detrimental effects of e-cigarette usage on pulmonary function. Joshi et al conducted a study that revealed the harmful effects of e-cigarette usage, including airway irritation, oxidative stress, inflammation, and reduced pulmonary function.[16]

The research conducted by Thirion-Romero et al revealed that e-cigarettes emit aerosols that contain a range of detrimental compounds, including nicotine, propylene glycol, and flavoring ingredients.[8] These components have the potential to induce oxidative stress and inflammation in the respiratory system. Oxidative stress occurs when there is an imbalance between the generation of free radicals and the body's ability to remove them. This can cause damage to the cells in the lung tissues, making respiratory problems worse.

Furthermore, a study conducted by Simanjuntak et al revealed that those who use e-cigarettes exhibit worse pulmonary function in comparison to individuals who do not smoke, which aligns with the results of the present study.[20] Gotts et al conducted a study where they explicitly assessed pulmonary function metrics, such as FEV_1 and FVC, and observed notable decreases in these values among individuals who use e-cigarettes. According to their study, prolonged exposure to e-cigarette aerosols may gradually harm pulmonary function, maybe as a result of inhaling harmful compounds found in e-cigarette vapor.[9] The diminished pulmonary function reported in their study closely corresponds to the decreased FEV_1 and FVC values identified in our research, suggesting a consistent pattern of respiratory impairment linked to the use of e-cigarettes.

Furthermore, the research conducted by Chaiton et al highlighted the significance of inflammation in the respiratory tract resulting from the use of e-cigarettes. It was shown that frequent exposure to e-cigarette aerosols results in chronic inflammation, which can lead to lasting harm to the epithelial cells that line the airways. This inflammation not only diminishes pulmonary function but also heightens vulnerability to respiratory infections and chronic ailments such as asthma and COPD. The study found that e-cigarette use leads to an inflammatory response, which involves the production of pro-inflammatory cytokines and chemokines.[10] This reaction is consistent with the

observed decrease in important pulmonary function indicators among e-cigarette users.

In addition, Taylor et al conducted a study to examine the effects of e-cigarette usage on lung health and obtained comparable findings. The study conducted by Taylor et al entailed a longitudinal examination of pulmonary function in those who use e-cigarettes and those who do not smoke, spanning multiple years. According to their findings, individuals who use e-cigarettes experienced a faster decrease in pulmonary function compared to those who do not smoke, emphasizing the possible negative consequences of long-term e-cigarette usage.[6] This study corroborates our findings by illustrating that the detrimental effect of e-cigarettes on pulmonary function is not restricted to immediate exposure but persists with long-term usage, leading to substantial deterioration in respiratory health.

Garavaglia et al conducted a study that investigated the molecular pathways responsible for the respiratory effects of e-cigarettes. Their research has revealed distinct pathways by which e-cigarette vapor triggers oxidative stress and inflammation at the cellular level. Garavaglia et al discovered that e-cigarette aerosols stimulate the nuclear factor-kappa B (NF-κB) pathway, which is a crucial controller of inflammatory reactions. The initiation of this pathway results in the generation of inflammatory mediators, which contribute to the reported decline in pulmonary function.[21] These molecular insights enhance our comprehension of the basic mechanisms behind the respiratory dysfunction induced by e-cigarette usage, supporting the conclusions of our research.

The study conducted by Gugala et al investigated the comparative impact of conventional cigarettes and e-cigarettes on pulmonary function. According to their findings, although e-cigarettes may be seen as a safer option, they nonetheless pose substantial hazards to respiratory health. Gugala et al discovered that both conventional cigarette smokers and e-cigarette users experienced comparable rates of deterioration in pulmonary function, indicating that e-cigarettes are not a completely safe alternative.[17] This comparison research supports our findings, confirming that the use of e-cigarettes results in substantial declines in pulmonary function and highlighting the importance of being cautious when advertising e-cigarettes as a safer alternative for nicotine intake.

There are various factors that can account for the observed disparities in pulmonary function between those who use e-cigarettes and those who do not smoke. E-cigarettes administer nicotine and other compounds directly to the respiratory system, inducing inflammation and oxidative stress. Nicotine has been found to induce the secretion of pro-inflammatory cytokines, which can harm lung tissue and hinder respiratory performance.[22] Excessive production of pro-inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), can cause chronic inflammation despite their role in the body's immunological response. Chronic inflammation can lead to fibrosis and hypertrophy of pulmonary tissue, resulting in decreased lung compliance and impaired respiratory expansion.[23]

In addition, e-cigarettes emit aerosols that consist of fine particulate matter capable of deeply penetrating the lungs, leading to additional harm and inflammation. These minute particles, commonly known as ultrafine particles, have a small size that allows them to penetrate the alveoli, which are the small air sacs in the lungs where gas exchange takes place. The accumulation of these particles in the alveoli might result in localized inflammation and hinder the lungs' capacity to efficiently oxygenate the blood. In addition, e-cigarette aerosols frequently contain other noxious components, like heavy metals (such as lead, nickel, and cadmium), volatile organic compounds, and flavoring additives like diacetyl, which have been associated with respiratory illnesses.[24]

The existence of these detrimental compounds might worsen oxidative stress, a state in which the generation of dangerous molecules known as free

radicals surpasses the body's capacity to counteract them. Oxidative stress can lead to substantial cellular harm, especially to the epithelial cells that form the lining of the respiratory system. This damage can weaken the protective function of the lungs, rendering them more vulnerable to infections and other environmental pollutants.[25]

Moreover, the repeated exposure to these harmful substances might trigger the activation of different cellular signaling pathways that stimulate inflammation and the restructuring of tissues. For instance, exposure to e-cigarette aerosol has been found to trigger the activation of the nuclear factor-kappa B (NF-κB) pathway, which plays a crucial role in regulating the inflammatory response.[26] Activation of this pathway might result in the synthesis of supplementary inflammatory mediators, so prolonging a cycle of inflammation and causing harm to the tissues.[27]

Another crucial process is the influence of e-cigarette use on the immune system. E-cigarettes can modify the immune response by impacting the functioning of immune cells in the lungs, specifically macrophages and neutrophils. These cells have essential functions in removing infections and debris from the respiratory tract. Exposure to e-cigarettes can cause these immune cells to perform poorly, which can result in a higher likelihood of respiratory infections and a reduced capacity to heal damaged lung tissue.[27]

The findings of this study have substantial ramifications for public health. Due to the rising popularity of e-cigarettes, especially among young individuals, it is necessary to increase awareness and provide education regarding the potential risks associated with their usage. Healthcare practitioners must diligently evaluate pulmonary function in individuals who use e-cigarettes and offer appropriate counseling regarding the potential hazards. Policymakers should take into account these findings when formulating rules and guidelines for the use of e-cigarettes to safeguard public health, especially among vulnerable populations.

LIMITATION

Although this study offers valuable insights into the effects of e-cigarette usage on pulmonary function, it is vital to recognize its various limitations. The cross-sectional design limits conclusions about long-term effects. Longitudinal studies are necessary to evaluate the cumulative effect of e-cigarette usage on respiratory health over a while. Furthermore, the study depended on self-reported data regarding e-cigarette usage, which could potentially be influenced by recall bias. Subsequent research should take into account the utilization of unbiased indicators, like as biomarkers of exposure, to more precisely evaluate the usage of e-cigarettes.

CONCLUSION

This study demonstrated that e-cigarette use in young adults aged 20–30 years in Jakarta is associated with impaired pulmonary function compared to non-smokers. Longer and more frequent use was associated with greater lung impairment, suggesting long-term risks.

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CONFLICT OF INTEREST

None.

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Original Article

Analysis of Pulmonary Function between E-Cigarette Users and Non-Smokers Aged 20–30 Years in Jakarta

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Abstract

Background: This study aimed to compare pulmonary function between e-cigarette users and non-smokers aged 20–30 years in Jakarta.

Methods: A cross-sectional study was carried out between May 2023 and May 2024 at SMC Clinic Jakarta, Ibnusina Hospital Jakarta, and Naura Medika Clinic Depok. The sample consisted of 65 individuals who used e-cigarettes and 63 individuals who did not smoke. Spirometry was employed to evaluate pulmonary function by measuring forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), and the FEV_1/FVC ratio. The data were analyzed using independent t-tests using IBM SPSS software version 25.0.

Results: The study revealed substantial disparities in pulmonary function between individuals who use e-cigarettes and those who do not smoke. Individuals who use e-cigarettes had significantly reduced FEV_1 at 3.02±0.50 L and FVC at 4.00±0.47 L, in comparison to non-smokers (FEV_1=3.51±0.57 L; FVC=4.57±0.50 L). E-cigarette users exhibited a considerably lower FEV_1/FVC ratio (74.86±5.55) compared to non-smokers (79.29±5.11), suggesting a higher occurrence of obstructive airway diseases.

Conclusion: Young adults aged 20-30 years in Jakarta who use e-cigarettes experience a decrease in pulmonary function. The results emphasize the possible respiratory hazards associated with the use of e-cigarettes and emphasize the necessity for greater awareness and regulatory actions to tackle these hazards.

Keywords: e-cigarette, pulmonary function, respiratory health, spirometry, young adults

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INTRODUCTION

Over the past several years, the prevalence of e-cigarettes, also referred to as vaping, has experienced a significant rise, especially among the younger demographic.[1] E-cigarettes are frequently promoted as a less hazardous substitute for conventional tobacco smoking and as an efficacious means of quitting smoking.[2]

Nevertheless, the health consequences of using e-cigarettes for an extended time remain incompletely comprehended, and there is a continuing dispute among scientists regarding their safety.[2] This study seeks to enhance the ongoing discourse by examining pulmonary function in individuals aged 20-30 years who use e-cigarettes, as compared to non-smokers, in Jakarta, a prominent urban hub in Indonesia.

E-cigarettes were initially introduced to the market in the early 2000s and have subsequently garnered significant global popularity.[3] These devices function by applying heat to a liquid (sometimes called e-liquid or vape juice) that contains nicotine, flavorings, and other substances.[4] The resulting aerosol is then inhaled. E-cigarettes differ from ordinary cigarettes in that they do not combust tobacco, hence eliminating the generation of numerous toxic by-products of combustion.[5] This disparity has resulted in the assumption that e-cigarettes are a more secure alternative for nicotine ingestion.[3]

The popularity of e-cigarettes, particularly among younger populations, has been further enhanced by marketing efforts and the introduction of a diverse range of attractive flavors. Recent polls indicate that a substantial proportion of young individuals have experimented with vaping, and a considerable number have subsequently become regular users.[3] Although e-cigarettes are widely used, there is still significant ambiguity about the potential long-term impact on respiratory health.

Although e-cigarettes are typically seen as less detrimental than conventional cigarettes, they nonetheless pose dangers. The aerosol emitted by e-cigarettes contains nicotine, a highly addictive stimulant, along with other potentially hazardous compounds such as heavy metals, volatile organic compounds, and flavoring ingredients that can be dangerous when breathed.[6,7]

Multiple studies have demonstrated that the use of e-cigarettes can result in respiratory problems.[8] Immediate consequences documented encompass inflammation of the throat and airways, coughing, and difficulty breathing. Of greater worry are the potential long-term effects on lung health, which are yet completely unknown.[9,10]

Recent findings indicate that the use of e-cigarettes might be a contributing factor to the development of long-term respiratory disorders, including asthma and chronic obstructive pulmonary disease (COPD).[9] Moreover, there are apprehensions over the possibility of e-cigarettes acting as a conduit to conventional smoking, especially among young individuals.[7,10]

Pulmonary function is a key marker of lung health, typically measured by spirometry.[11] Important variables assessed in spirometry include forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), and the FEV_1/FVC ratio. FEV1 quantifies the quantity of air that an individual can forcefully expel during a single second, whereas FVC denotes the total amount of air exhaled during a compelled breath. The FEV_1/FVC ratio is utilized for the diagnosis of obstructive and restrictive airway diseases.[12]

Prior studies have confirmed that smoking conventional cigarettes results in a deterioration of pulmonary function, characterized by decreased FEV_1, FVC, and a diminished FEV_1/FVC ratio.[13] Nevertheless, the effect of e-cigarettes on these factors remains uncertain. Several studies have indicated a decrease in pulmonary function among those who use e-cigarettes. However, other investigations have observed no notable disparities when compared to individuals who do not smoke.[14] These differences highlight the need for further research.

Jakarta, the capital city of Indonesia, is an ideal location for this study because of its dense population and the increasing frequency of e-cigarette usage among young adults.[11] Indonesia possesses one of the highest smoking prevalence rates globally, and the emergence of e-cigarettes has brought a fresh aspect to the nation's public health scenario.[15] It is essential to comprehend the impact of e-cigarette usage on pulmonary function in this particular situation to formulate efficient public health initiatives and laws.

This study aimed to compare pulmonary function between e-cigarette users and non-smokers aged 20–30 in Jakarta. This study intends to get insights into the initial impact of e-cigarette usage on respiratory health by specifically targeting a young adult group. The study will specifically assess and analyze the FEV_1, FVC, and the ratio of FEV_1 to FVC to discover if there are any significant variations between the two groups.

METHODS

This study was conducted using a cross-sectional method to compare pulmonary function between e-cigarette users and non-smokers aged 20-30 years at the SMC Clinic Jakarta. The study period was from May 2023 to May 2024. The inclusion criteria for this study were young adults aged 20-30 years who were either e-cigarette users or non-smokers.

Participants with incomplete medical records, incomplete smoking history, those who refused or were unable to take part in this study were excluded.

Participants were recruited through purposive sampling at RS Ibnusina, SMC Clinic, and Naura Medika Clinic. A total of 128 participants met the inclusion criteria and were willing to participate in the study. Among them, 65 were e-cigarette users and 63 were non-smokers. Each subject signed the informed consent.

Participants categorized as e-cigarette users in this study were defined based on their duration and frequency of e-cigarette usage, as reported through structured questionnaires. Duration was categorized into three groups: short-term (<1 year), medium-term (1-3 years), and long-term (>3 years) users. Frequency of usage was classified as infrequent (≤3 days/week), moderate (4-6 days/week), and frequent (daily use).

Participants underwent spirometry tests to measure pulmonary function, including FEV_1, FVC, and the FEV_1/FVC ratio. Each participant performed three spirometry trials and the best result was used for analysis. Spirometry was conducted under standardized conditions to ensure accuracy and reliability. Data were collected through questionnaires that included demographic information (age, gender) and details of e-cigarette use (duration and frequency). Spirometry data were recorded and analyzed to assess pulmonary function.

The data were processed and analyzed using IBM SPSS software version 25.0 with a 95% confidence level. Descriptive statistics were used to summarize the demographic characteristics and pulmonary function parameters of the two groups. An independent t-test was used to compare pulmonary function parameters (FEV_1, FVC, FEV_1/FVC) between e-cigarette users and non-smokers to determine if there were significant differences between the groups. The value of $P<0.05$ was considered statistically significant.

RESULTS

A total of 128 participants were included in the study, consisting of 65 e-cigarette users and 63 non-smokers. The mean age of e-cigarette users was 24.83±3.13 years, while that of non-smokers was 24.33±3.10 years. The gender distribution showed a predominance of males in the e-cigarette group (40 males and 25 females), whereas the non-smoker group comprised 29 males and 34 females (Table 1).

Table 1. Demographic Characteristic

Characteristic	E-Cigarette Users (n=65)	Non-Smokers (n=63)
Age (mean±SD)	24.83±3.13	24.33±3.10
Gender		
Male	40	29
Female	25	34

Analysis of pulmonary function among e-cigarette users revealed a dose-dependent relationship between duration and frequency of usage and pulmonary function decline. Long-term users (>3 years) had significantly lower mean FEV_1 (2.81±0.42 L) and FVC (3.80±0.44 L) compared to short-term users (<1 year; FEV_1=3.20±0.51 L; FVC=4.15±0.48 L), with $P<0.01$. Similarly, frequent daily users exhibited reduced pulmonary function compared to infrequent users ($P<0.05$) (Table 2).

Table 2. Pulmonary Function by Duration and Frequency of e-cigarette Use

Category	FEV_1 (L)	FVC (L)	FEV_1/FVC (%)
Duration			
Short-term (<1 yr)	3.20±0.51	4.15±0.48	77.1±5.4
Medium-term (1–3 yr)	3.04±0.47	4.00±0.46	75.0±5.2
Long-term (>3 yr)	2.81±0.42	3.80±0.44	73.0±4.7
Frequency			
Infrequent (≤3 d/wk)	3.17±0.52	4.11±0.50	76.4±5.6
Moderate (4–6 d/wk)	3.03±0.48	3.95±0.47	74.8±5.1
Frequent (d)	2.89±0.46	3.91±0.45	73.2±4.8

Significant differences were observed in spirometry parameters between e-cigarette users and non-smokers (Table 3). E-cigarette users demonstrated significantly lower FEV_1 (3.02±0.50 L vs 3.51±0.57 L), FVC (4.00±0.47 L vs 4.57±0.50 L), and FEV_1/FVC ratio (74.86±5.55% vs 79.29±5.11%), with all comparisons yielding $P<0.001$.

Table 3. Pulmonary Function Parameters

Parameter	E-Cigarette Users	Non-Smokers	t-statistic	*P*
FEV_1	3.02±0.50	3.51±0.57	–5.22	<0.001
FVC	4.00±0.47	4.57±0.50	–6.58	<0.001
FEV_1/FVC	74.86±5.55	79.29±5.11	–4.70	<0.001

The study revealed a statistically significant decrease in the average FEV_1 among e-cigarette users compared to non-smokers. More precisely, the average FEV_1 for individuals who use e-cigarettes was 3.02±0.50 L, while for individuals who do not smoke, it was 3.51±0.57 L. An independent t-test was conducted to assess the difference in means. The t-statistic obtained was -5.22, with $P<0.001$. The highly significant value of *P* suggests a robust statistical difference between the two groups.

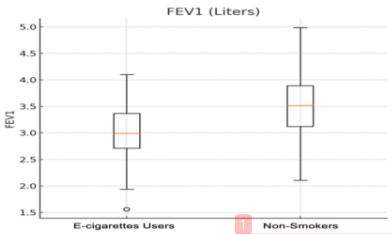

Figure 1. Comparison of FEV_1 Between e-cigarette users and Non-Smokers

The average FVC for individuals who use e-cigarettes in this study was 4.00±0.47 L, which was notably lower than the FVC of 4.57±0.50 L reported in individuals who do not smoke. The observed difference was statistically significant, as indicated by a t-statistic of -6.58 and $P<0.001$.

The average FEV_1/FVC ratio for individuals who use e-cigarettes was 74.86±5.55, while it was 79.29±5.11 for individuals who do not smoke. The observed difference was statistically significant, as indicated by a t-statistic of -4.70 and $P<0.001$. E-cigarette users exhibit a lower FEV_1/FVC ratio, indicating a greater occurrence of obstructive airway disorders, which are characterized by diminished airflow and challenges in exhaling. These findings indicate that the use of e-cigarettes may play a role in the emergence of illnesses such as COPD and asthma.

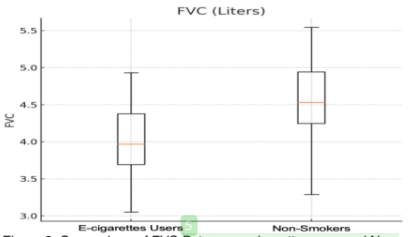

Figure 2. Comparison of FVC Between e-cigarette users and Non-Smokers

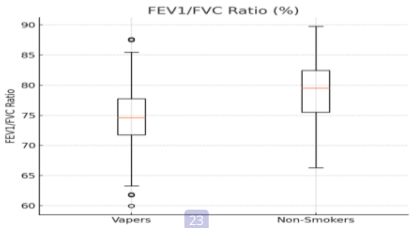

Figure 3. FEV1 and FVC Ratio Between e-cigarette users and Non-Smokers
E-cigarettes Users

DISCUSSION

FEV_1 is a crucial metric for assessing pulmonary function, which precisely measures the amount of air an individual can forcefully exhale during a duration of one second. It is commonly employed to diagnose and track respiratory diseases.[12] The average FEV_1 for individuals who use e-cigarettes was significantly lower (3.02±0.50 L) in comparison to individuals who do not smoke (3.51±0.57 L). The reduced FEV_1 observed in e-cigarette users indicates that these individuals may have impaired pulmonary function, possibly as a result of inhaling compounds present in e-cigarette aerosols. These substances can induce inflammation and harm the respiratory system.

The t-statistic for FEV_1 yielded a value of -5.22, while the $P<0.001$. These results indicate a substantial and statistically significant difference between the two groups. This discovery is consistent with prior studies

indicating that the use of e-cigarettes can result in a decline in pulmonary function.[16] This decline is attributed to the inhalation of dangerous compounds found in the vapor, including nicotine, propylene glycol, and various flavorings. These substances have the potential to induce inflammation and harm to the airways.[17]

The t-statistic value for FVC is -6.58 with $P<0.001$. The diminished FVC observed in individuals who use e-cigarettes indicates that their lung capacity is damaged, likely as a result of prolonged exposure to e-cigarette aerosols. This exposure may cause inflammation, tissue harm, and hinder lung expansion and contraction.

The FEV_1/FVC ratio is a calculated measurement that offers vital information about the existence of obstructive or restrictive lung disorders. The calculation involves dividing the FEV_1 by the FVC and expressing the result as a percentage.[18] In persons who are in good health, this ratio is generally elevated, which suggests that there is a smooth and effective movement of air through the respiratory passages.

The notable disparities in pulmonary function indicators between those who use e-cigarettes and those who do not smoke underscore the possible negative impacts of e-cigarette usage on respiratory well-being. The diminished FEV_1 and FVC observed in individuals who use e-cigarettes indicate a weakened pulmonary function, potentially resulting in chronic respiratory problems. E-cigarette users with a lower FEV_1/FVC ratio are more likely to have obstructive airway problems, potentially leading to chronic respiratory disorders.

The results of this study align with prior research that has documented the detrimental effects of e-cigarette usage on pulmonary function. Joshi et al conducted a study that revealed the harmful effects of e-cigarette usage, including airway irritation, oxidative stress, inflammation, and reduced pulmonary function.[16]

The research conducted by Thirion-Romero et al revealed that e-cigarettes emit aerosols that contain a range of detrimental compounds, including nicotine, propylene glycol, and flavoring ingredients.[8] These components have the potential to induce oxidative stress and inflammation in the respiratory system. Oxidative stress occurs when there is an imbalance between the generation of free radicals and the body's ability to remove them. This can cause damage to the cells in the lung tissues, making respiratory problems worse.

Furthermore, a study conducted by Simanjuntak et al revealed that those who use e-cigarettes exhibit worse pulmonary function in comparison to individuals who do not smoke, which aligns with the results of the present study.[20] Gotts et al conducted a study where they explicitly assessed pulmonary function metrics, such as FEV_1 and FVC, and observed notable decreases in these values among individuals who use e-cigarettes. According to their study, prolonged exposure to e-cigarette aerosols may gradually harm pulmonary function, maybe as a result of inhaling harmful compounds found in e-cigarette vapor.[9] The diminished pulmonary function reported in their study closely corresponds to the decreased FEV_1 and FVC values identified in our research, suggesting a consistent pattern of respiratory impairment linked to the use of e-cigarettes.

Furthermore, the research conducted by Chaiton et al highlighted the significance of inflammation in the respiratory tract resulting from the use of e-cigarettes. It was shown that frequent exposure to e-cigarette aerosols results in chronic inflammation, which can lead to lasting harm to the epithelial cells that line the airways. This inflammation not only diminishes pulmonary function but also heightens vulnerability to respiratory infections and chronic ailments such as asthma and COPD. The study found that e-cigarette use leads to an inflammatory response, which involves the production of pro-inflammatory cytokines and chemokines.[10] This reaction is consistent with the

observed decrease in important pulmonary function indicators among e-cigarette users.

In addition, Taylor et al conducted a study to examine the effects of e-cigarette usage on lung health and obtained comparable findings. The study conducted by Taylor et al entailed a longitudinal examination of pulmonary function in those who use e-cigarettes and those who do not smoke, spanning multiple years. According to their findings, individuals who use e-cigarettes experienced a faster decrease in pulmonary function compared to those who do not smoke, emphasizing the possible negative consequences of long-term e-cigarette usage.[6] This study corroborates our findings by illustrating that the detrimental effect of e-cigarettes on pulmonary function is not restricted to immediate exposure but persists with long-term usage, leading to substantial deterioration in respiratory health.

Garavaglia et al conducted a study that investigated the molecular pathways responsible for the respiratory effects of e-cigarettes. Their research has revealed distinct pathways by which e-cigarette vapor triggers oxidative stress and inflammation at the cellular level. Garavaglia et al discovered that e-cigarette aerosols stimulate the nuclear factor-kappa B (NF-κB) pathway, which is a crucial controller of inflammatory reactions. The initiation of this pathway results in the generation of inflammatory mediators, which contribute to the reported decline in pulmonary function.[21] These molecular insights enhance our comprehension of the basic mechanisms behind the respiratory dysfunction induced by e-cigarette usage, supporting the conclusions of our research.

The study conducted by Gugala et al investigated the comparative impact of conventional cigarettes and e-cigarettes on pulmonary function. According to their findings, although e-cigarettes may be seen as a safer option, they nonetheless pose substantial hazards to respiratory health. Gugala et al discovered that both conventional cigarette smokers and e-cigarette users experienced comparable rates of deterioration in pulmonary function, indicating that e-cigarettes are not a completely safe alternative.[17] This comparison research supports our findings, confirming that the use of e-cigarettes results in substantial declines in pulmonary function and highlighting the importance of being cautious when advertising e-cigarettes as a safer alternative for nicotine intake.

There are various factors that can account for the observed disparities in pulmonary function between those who use e-cigarettes and those who do not smoke. E-cigarettes administer nicotine and other compounds directly to the respiratory system, inducing inflammation and oxidative stress. Nicotine has been found to induce the secretion of pro-inflammatory cytokines, which can harm lung tissue and hinder respiratory performance.[22] Excessive production of pro-inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), can cause chronic inflammation despite their role in the body's immunological response. Chronic inflammation can lead to fibrosis and hypertrophy of pulmonary tissue, resulting in decreased lung compliance and impaired respiratory expansion.[23]

In addition, e-cigarettes emit aerosols that consist of fine particulate matter capable of deeply penetrating the lungs, leading to additional harm and inflammation. These minute particles, commonly known as ultrafine particles, have a small size that allows them to penetrate the alveoli, which are the small air sacs in the lungs where gas exchange takes place. The accumulation of these particles in the alveoli might result in localized inflammation and hinder the lungs' capacity to efficiently oxygenate the blood. In addition, e-cigarette aerosols frequently contain other noxious components, like heavy metals (such as lead, nickel, and cadmium), volatile organic compounds, and flavoring additives like diacetyl, which have been associated with respiratory illnesses.[24]

The existence of these detrimental compounds might worsen oxidative stress, a state in which the generation of dangerous molecules known as free

radicals surpasses the body's capacity to counteract them. Oxidative stress can lead to substantial cellular harm, especially to the epithelial cells that form the lining of the respiratory system. This damage can weaken the protective function of the lungs, rendering them more vulnerable to infections and other environmental pollutants.[25]

Moreover, the repeated exposure to these harmful substances might trigger the activation of different cellular signaling pathways that stimulate inflammation and the restructuring of tissues. For instance, exposure to e-cigarette aerosol has been found to trigger the activation of the nuclear factor-kappa B (NF-κB) pathway, which plays a crucial role in regulating the inflammatory response.[26] Activation of this pathway might result in the synthesis of supplementary inflammatory mediators, so prolonging a cycle of inflammation and causing harm to the tissues.[27]

Another crucial process is the influence of e-cigarette use on the immune system. E-cigarettes can modify the immune response by impacting the functioning of immune cells in the lungs, specifically macrophages and neutrophils. These cells have essential functions in removing infections and debris from the respiratory tract. Exposure to e-cigarettes can cause these immune cells to perform poorly, which can result in a higher likelihood of respiratory infections and a reduced capacity to heal damaged lung tissue.[27]

The findings of this study have substantial ramifications for public health. Due to the rising popularity of e-cigarettes, especially among young individuals, it is necessary to increase awareness and provide education regarding the potential risks associated with their usage. Healthcare practitioners must diligently evaluate pulmonary function in individuals who use e-cigarettes and offer appropriate counseling regarding the potential hazards. Policymakers should take into account these findings when formulating rules and guidelines for the use of e-cigarettes to safeguard public health, especially among vulnerable populations.

LIMITATION

Although this study offers valuable insights into the effects of e-cigarette usage on pulmonary function, it is vital to recognize its various limitations. The cross-sectional design limits conclusions about long-term effects. Longitudinal studies are necessary to evaluate the cumulative effect of e-cigarette usage on respiratory health over a while. Furthermore, the study depended on self-reported data regarding e-cigarette usage, which could potentially be influenced by recall bias. Subsequent research should take into account the utilization of unbiased indicators, like as biomarkers of exposure, to more precisely evaluate the usage of e-cigarettes.

CONCLUSION

This study demonstrated that e-cigarette use in young adults aged 20–30 years in Jakarta is associated with impaired pulmonary function compared to non-smokers. Longer and more frequent use was associated with greater lung impairment, suggesting long-term risks.

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CONFLICT OF INTEREST

None.

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None.

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