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A Comparative Study of Pulmonary Function Test Results in AC Users Versus Non-Users

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Abstract:

- ***Introduction:***

Air conditioning (AC) has become a widespread necessity in modern environments, especially in urban and industrial areas. Despite its benefits in providing comfort, concerns are rising regarding the long-term effects of AC exposure on respiratory health. This study aims to compare pulmonary function test (PFT) results between individuals regularly exposed to air conditioning and those not exposed to it, to better understand the potential effects on lung function.

- ***Aim and Objectives:***

This paper was intended to evaluate the impact of air conditioning on lung function by comparing PFT outcomes of people who use air conditioning and those who do not. The first objective was to determine if respiratory health is affected after exposure to air conditioning.

- ***Methods:***

A cross-sectional comparative study was conducted for a period of 2.5 years. Two hundred participants from Kalol, Gandhinagar, Gujarat, 5 years of study. The participants were categorized into two groups: AC users were defined as those people who had used air conditioning for more than six hours a day for at least one year while non-AC users were those who had no regular exposure to AC. Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), Peak Expiratory Flow Rate (PEFR) and Forced Expiratory Flow 25-75% (FEF25-75%) pulmonary function tests were conducted using Portable Spirometer (Helios 702). The data was analyzed by unpaired t-test and chi-square test.

- ***Results:***

Results demonstrated significant reductions in lung function among AC users compared to non-AC users. Predicted FVC was significantly lower in AC users (2.31 ± 0.91 L) compared to non-AC users (3.37 ± 0.92 L, $p < 0.0001$). Similarly, predicted PEFR, FEF25-75% were significantly lower in AC users ($p = 0.04$ for both parameters). No significant differences were found in FEV1 or FEV1/FVC ratio among 2 groups ($p = 0.41$ and 0.89, respectively). The findings suggest that prolonged AC exposure can reduce lung volumes and affect small airway function.

- ***Conclusion:***

This study demonstrates that prolonged exposure to air conditioning may adversely affect lung volumes and airflow, particularly in the smaller airways. No significant differences were observed in FEV1 and FEV1/FVC ratio, the significant

reductions in FVC, FEFR, and FEF25-75% highlight the potential respiratory risks associated with chronic AC exposure. Public health initiatives should emphasize proper AC maintenance and monitoring of lung function in individuals exposed to air conditioning for extended periods, particularly in occupational settings.

Keywords: *Air Conditioning, Pulmonary Function Tests, FVC, FEV1, Small Airway Function, Respiratory Health, Occupational Exposure.*

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I. INTRODUCTION

Research into the effects of AC on pulmonary function in individuals, compared to those who do not use AC, has drawn significant interest, largely due to the widespread use of AC systems in both homes and workplaces. As urbanization accelerates and more individuals are exposed to regulated indoor climates, it becomes crucial to understand how air conditioning might affect respiratory health. AC systems are typically appreciated for their ability to control temperature and humidity, especially during extreme weather. However, there is growing concern regarding their influence on indoor air quality and the potential long-term effects on lung health. When not properly maintained, AC units can circulate airborne particles, such as dust, pollen, and microorganisms like mold and bacteria. This brings up concerns about their effect on respiratory health. PFTs serve as vital tools for evaluating lung health, measuring parameters like FVC and FEV1 (1). These measurements offer valuable insights into how environmental factors, like AC use, might influence respiratory function.AC systems have become commonplace, especially in areas with severe weather conditions. While they offer relief from high temperatures and help maintain humidity levels, they also present a challenge to indoor air quality. Although AC systems can filter out pollutants from the outside air, they may also recirculate allergens, dust, and harmful microorganisms if not properly serviced (2). Neglected systems can harbor mold and bacteria, which can degrade indoor air quality and pose health hazards. (3).

Research indicates that long-term exposure to air conditioning may lead to various respiratory issues, such as reduced lung function, dry throat, and a greater likelihood of respiratory infections. Al-Hazmi et al. (2012) observed that individuals frequently exposed to AC showed lower pulmonary function, evidenced by reductions in FVC and FEV1 (4). Similarly, Tanaka et al. (2010) reported higher rates of respiratory infections among regular AC users, highlighting the risks associated with prolonged exposure to air conditioning (2). PFTs are indispensable diagnostic methods used to assess lung function and understand how environmental and physiological factors might affect respiratory health. These non-invasive tests evaluate lung volume, capacity, airflow, and gas exchange, providing a detailed picture of lung health (1). Forced Vital Capacity (FVC) is the volume of air expelled during a forced expiration after a maximal inspiration while Forced Expiratory Volume in one second (FEV1) is the volume of air expired during the first second of forced expiration. The FEV1/FVC ratio serves as an important indicator for diagnosing obstructive and restrictive lung diseases (1). In this study, PFTs are employed to investigate how air conditioning affects lung function in both users and non-users.

Air conditioning affects respiratory health in both positive and negative ways. When well-maintained, AC systems can improve air quality by filtering allergens and particulates, which can be beneficial for people with asthma and COPD (5). Huang et al. (2016) pointed out that air conditioning systems improved the quality of life of COPD patients by reducing their exposure to outdoor pollutants and allergens (6). By decreasing humidity and pollen levels, these systems help establish an environment that reduces respiratory problems for those at risk (5). On the other hand, poorly maintained AC units can spread allergens, dust, and biological contaminants like mold and bacteria, leading to adverse respiratory effects (7). Jacobs et al. (2013) emphasized the importance of maintaining AC systems, as neglecting proper maintenance can worsen respiratory problems, especially for individuals with pre-existing conditions (7).

Comparative research examining pulmonary function in AC users and non-users offers valuable insights into the potential effects of AC on lung health. Such studies generally account for various factors, including age, smoking habits, and any pre-existing respiratory conditions, to ensure accurate comparisons. Results from these studies are mixed, with some suggesting that air conditioning can negatively affect lung function, while others indicate little to no impact (4).For example, Tanaka et al. (2010) conducted a study on healthy young adults to assess lung function differences between individuals exposed to air conditioning and those who were not. In their study, they found out that there was no difference in the lung function of the two groups after short-term exposure, meaning that air conditioning does not have an adverse effect on the healthy individuals in the short run (2). However, they stressed the importance of long-term studies to fully comprehend the chronic impact of air conditioning on respiratory health. In contrast, Al-Hazmi et al. (2012) observed that regular AC users had significantly lower FVC and FEV1 values compared to non-users, indicating that prolonged exposure to AC could potentially harm lung function over time (4). Understanding how AC affects lung health is crucial, especially in regions where AC usage is widespread. Given the growing dependence on air conditioning in homes, offices, and other indoor spaces, it is essential to examine the potential health risks and develop guidelines to minimize them. The findings from this research could shape public health policies on AC usage, air conditioning maintenance, and indoor air quality control to better protect respiratory health (9).

This study has the potential to impact AC maintenance protocols and public health guidelines, especially for high-risk groups. By examining both the immediate and long-term effects of air conditioning on respiratory health, the research seeks to provide a comprehensive insight into the possible risks and benefits linked to AC use. Additionally, it highlights the critical role of proper AC system upkeep and air quality control in promoting a healthier living environment (10).

In conclusion, this comparative study of pulmonary function in AC users versus non-users seeks to assess the link between air conditioning and respiratory health. Through the use of PFTs to measure lung function while controlling for various factors, this study aims to provide strong evidence on the health impacts of AC. The results may contribute to better AC maintenance practices, influence public health policies, and raise awareness about the need for maintaining high indoor air quality to safeguard respiratory health.

A. Aims & Objective:

➢ *Aim:*

The aim of the present investigation is to make awareness among the people, whose lifestyle have changed due to occupation, since they are exposed to AC.

➢ *Objectives:*

- To study the effect of using AC on various pulmonary function test.
- To study and compare the pulmonary function test in AC user and non AC users.

II. MATERIALS AND METHODS

This study was structured as a comparative analysis aimed at evaluating pulmonary function in individuals exposed to AC compared to those who do not use it. Conducted in Kalol, Gandhinagar, Gujarat, over a span of 2.5 year. For determining the appropriate sample size, the current investigation referred to a previous study conducted by Hulke et al., which examined PFTs in AC users. The sample size was calculated based on an effect size of 0.30 and a pooled standard deviation of 0.42 units. A total of 100 participants per group (200 total) was needed to achieve an 80% power and a 5% level of significance (two-sided), allowing for the detection of a true difference in means between AC users and non-users (11).

The control group included individuals aged 25 to 45 from both genders who did not use air conditioning. The case group comprised participants of the same age range who had been exposed to AC for more than six hours per day for at least one year, primarily including employees from sectors such as banking, multinational companies, and car driving. Exclusion criteria ruled out individuals younger than 25 or older than 45, smokers, those with irregular AC usage, participants with acute or chronic respiratory issues, individuals practicing yoga or regular exercise, and those with a history of neuromuscular disease or thoracic abnormalities, as well as non-cooperative subjects (1).

Data collection began with anthropometric measurements, including age, height, and weight. A preliminary clinical examination was conducted for both the control and case groups to rule out any existing medical issues. PFT were conducted using the Helios 702 Portable Spirometer, which complies with standards for lung function testing (12). Each participant was seated upright, and a nose clip was applied. The subjects were instructed on to use the device properly, placing the mouthpiece in their mouth while breathing into the apparatus. After completing a normal exhalation, participants were asked to take a slow, deep breath, followed by a forceful exhalation. They were encouraged to blow as hard as possible for at least six seconds, and values for FVC and FEV1 were recorded. This procedure was repeated three times, and the best result was used for analysis.

The study evaluated several parameters such as FVC which is the amount of air that can be exhaled from the lungs in one forced expiration after taking the deepest breath possible, which is normally between 3. 5 to 5. 5 liters. Another measured parameter was FEV1, which is the volume of air expelled in the first second of FVC and is used for diagnosing airway diseases. The FEV1/FVC ratio was also assessed in order to differentiate between obstructive and restrictive lung disorders. Also, Forced Expiratory Volume 25-75% (FEV25-75%) was considered, which is the mean expiratory flow rate during the middle portion of FVC and has normal values of approximately 300 L/min. Last but not the least, the Peak Expiratory Flow Rate (PEFR) which is the highest rate at which one can blow out air after a deep breath ranges between 350-600 L/min. The collected data were analyzed statistically by calculating the mean and standard deviation for each parameter for the study. The results between groups were compared using the unpaired t-test and the comparison of respiratory symptoms was done using the Chi-square test. Data analysis was performed using Microsoft Excel and SPSS10 software for Windows, ensuring statistical accuracy. Additionally, graphical representations such as charts and graphs were created to help visualize, analyze, and interpret the numerical data collected throughout the study.This comprehensive methodology provided an in-depth evaluation of the effects of air conditioning on pulmonary function, offering valuable insights into the respiratory health of individuals who were regularly exposed to AC compared to those who were not.

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III. RESULT

Table 1 Anthropometric Parameters of the study Population

S.no	Parameter	Non-AC users (mean ± SD)	AC users (mean ± SD)	p
1	Age (Years)	36.10 ± 13.90	36.38 ± 13.74	0.80
2	Height (cm)	168.60 ± 17.87	166 ± 17.4	0.23
3	Weight (kg)	67.77 ± 16.82	66.03 ± 15.45	0.68
4	Male/Female (n)	71/29	34/66	-

Table 2 Lung Function Parameters among AC user and non-users

S.no	Parameter	Non-AC users (mean ± SD)	AC users (mean ± SD)	p
1	Predicted FVC	3.37 ± 0.92	2.31 ± 0.91	<0.0001*
2	Predicted FEV1 (L)	2.78 ± 0.82	2.68 ± 0.82	0.41
3	Predicted PEFR (L/s)	8.45±1.82	7.92± 1.91	0.04*
4	Predicted FEF 25-75 (L's)	3.83± 0.93	3.53 + 1.05	0.04*
5	Predicted FEV1/FVC (%)	82.04 ±4.27	82.02 ±4.34	0.89

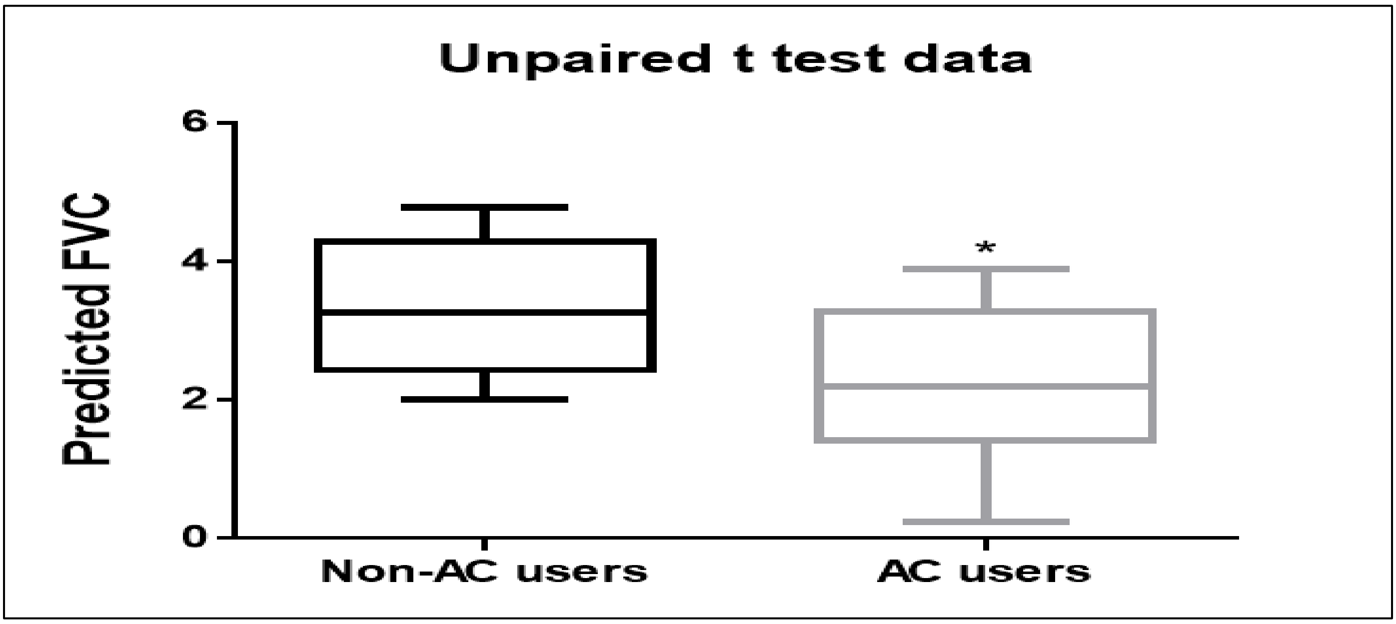

Fig 1 Comparison between Predicted FVC among study Groups

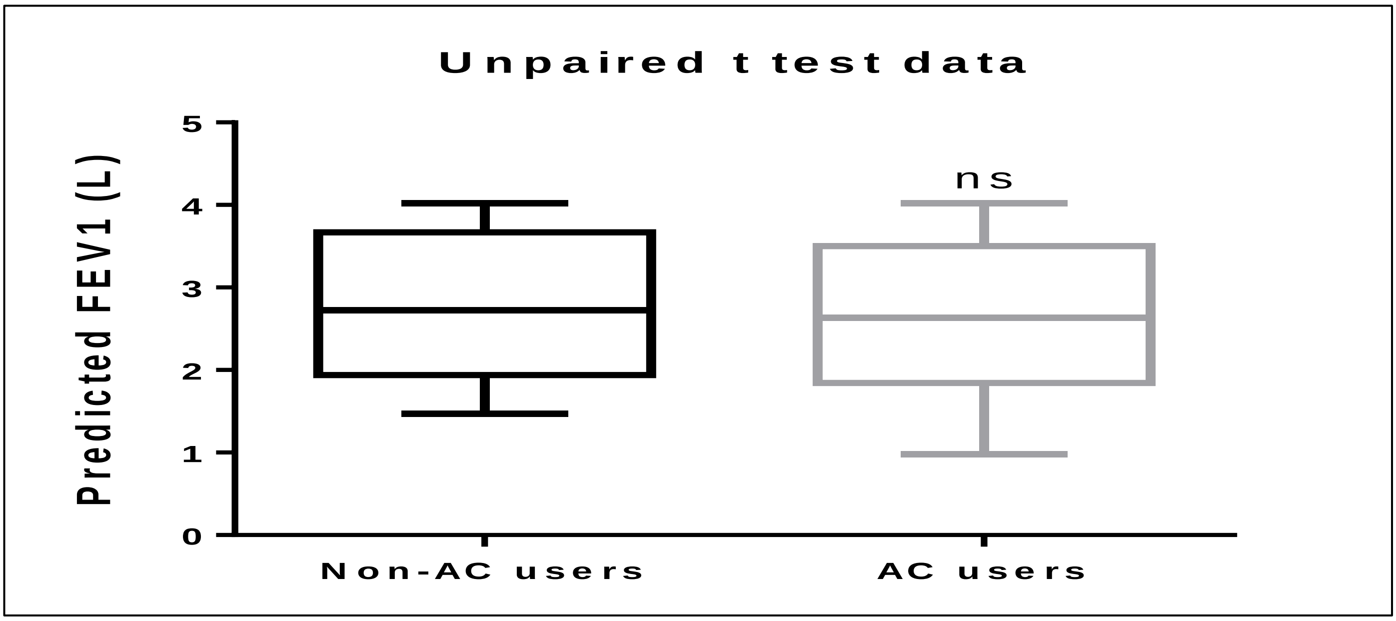

Fig 2 Comparison between Predicted FEV1 among study Groups

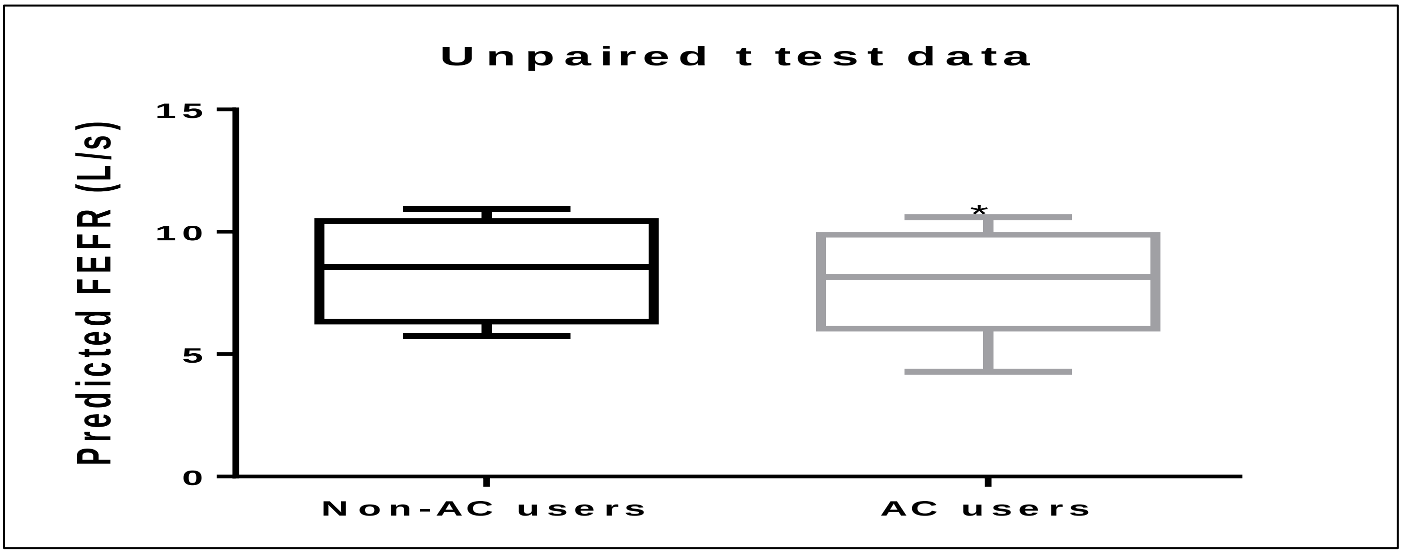

Fig 3 Comparison between predicted FEFR among study groups

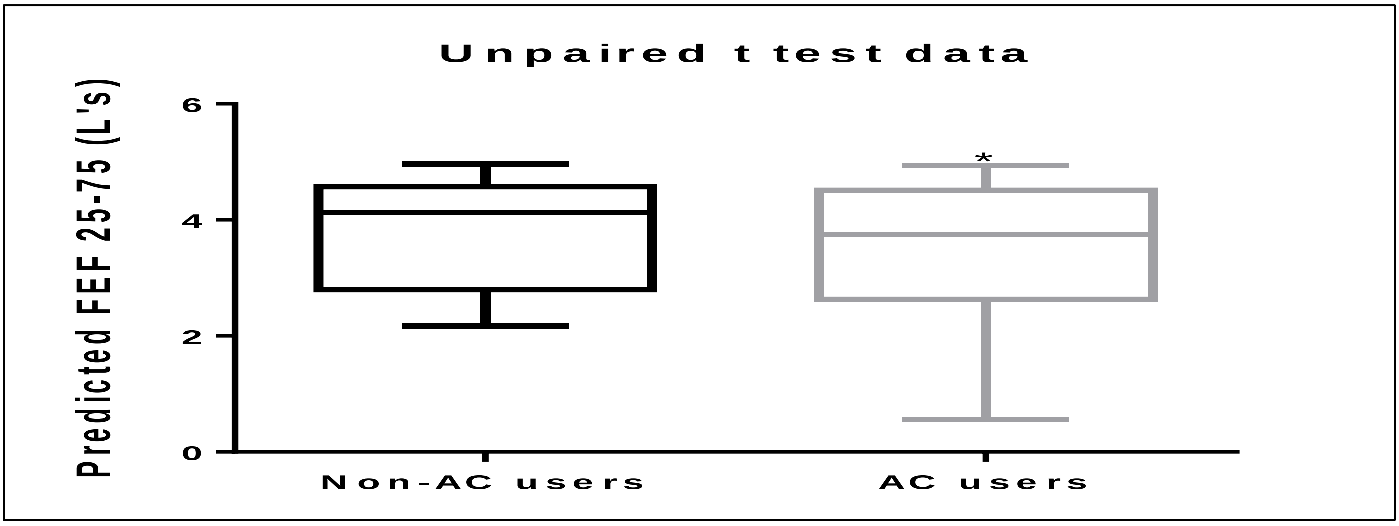

Fig 4 Comparison between Predicted FEF 25-75 among study Groups

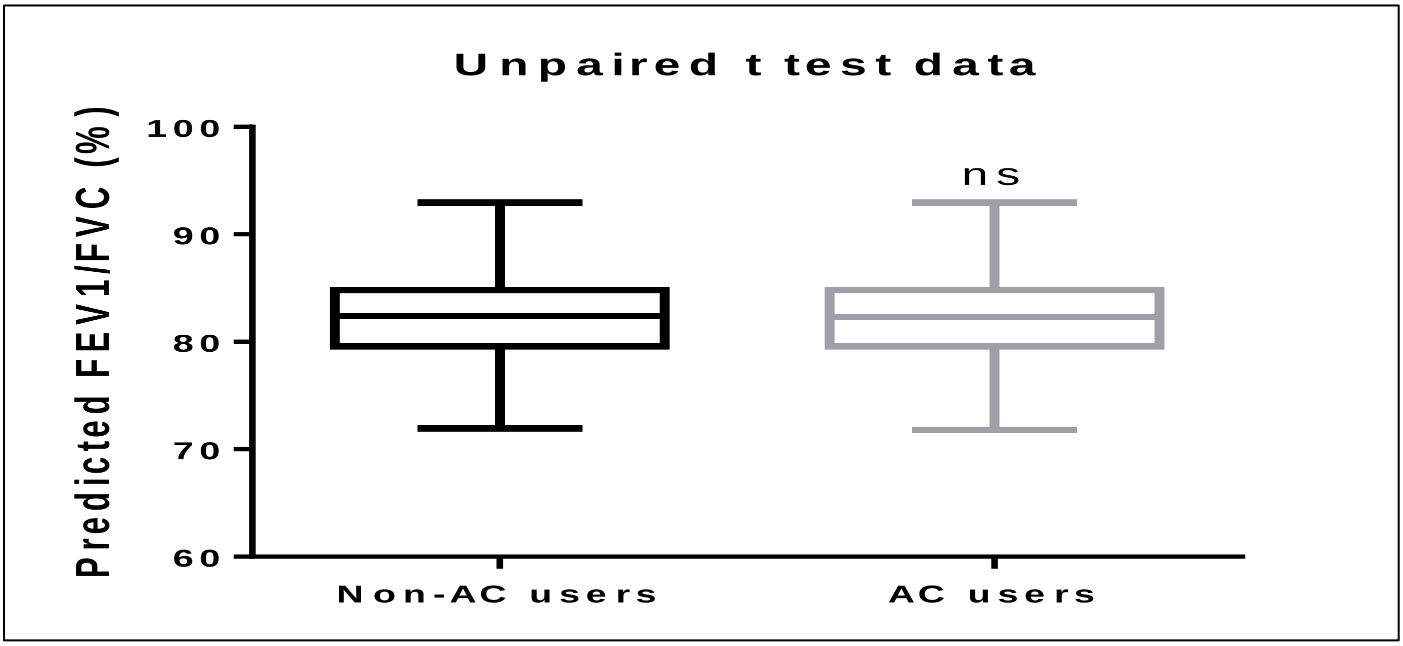

Fig 5 Comparison between predicted FEV1/FVC (%) among study groups

IV. DISCUSSION

The results of our study, provide key insights into how AC exposure affects pulmonary function. The primary goal was to compare lung function parameters between individuals who regularly used AC and those who did not. The study showed that there were differences in some of the lung function parameters and this indicated that exposure to AC for long time may have negative impact on respiratory health. However, some of our results differ from other studies, requiring further discussion and justification, while some findings align with previous research. The anthropometric analysis showed no significant differences between AC users and non-users in terms of age, height, or weight, with p-values of 0.80, 0.23, and 0.68, respectively, indicating that the two groups were comparable for assessing pulmonary function.

A notable finding was the reduced FVC among AC users compared to non-users. The mean FVC for non-AC users was 3.37 ± 0.92 L, while for AC users, it was significantly lower at 2.31 ± 0.91 L, with a p-value of <0.0001. This suggests that long-term AC exposure may negatively impact lung volumes, likely due to factors such as reduced air quality and inhalation of cooler, drier air in air-conditioned spaces. The lower FVC could point to restrictive lung disorders, indicating that AC exposure may predispose individuals to such conditions. Similar findings were reported by Hulke et al. (11) and Al-Hazmi et al. (3), who also found reduced FVC in individuals exposed to AC for prolonged periods. However, Tanaka et al. (2) found no significant differences in FVC between AC users and non-users, possibly due to differences in the duration and intensity of AC exposure. Our study's participants had consistent, prolonged AC exposure of more than six hours per day over at least one year, whereas Tanaka's participants experienced more intermittent exposure. (3) This prolonged exposure could explain the more pronounced effects on lung volumes observed in our study. Additionally, we found no significant reduction in FEV1 between AC users and non-users (p = 0.41), with both groups showing similar FEV1 values, aligning with Tanaka et al.'s results. However, Hulke et al. (11) reported significant reductions in FEV1 among AC users, possibly due to differences in baseline health conditions and AC exposure levels in their sample.

Interestingly, our study showed significant reductions in PEFR and (FEF25-75%) among AC users. The mean predicted FEFR was 7.92 ± 1.91 L/s in AC users compared to 8.45 ± 1.82 L/s in non-AC users (p=0.04), while the mean FEF25-75% was 3.53 ± 1.05 L/s for AC users versus 3.83 ± 0.93 L/s for non-users (p=0.04). These results suggest that prolonged AC exposure can impair small airway function. Reduced PEFR and FEF25-75% values, which are indicators of early-stage small airway dysfunction, may result from long-term AC exposure. Jacobs et al. (4) and Yoon et al. (5) also reported similar findings, further supporting our results. However, Seppänen et al. found no significant differences, likely because their study participants worked in well-maintained environments with advanced ventilation, unlike our study, which included individuals exposed to less-maintained AC systems. Poorly maintained AC units can circulate allergens, dust, and microbial particles, leading to airway inflammation and dysfunction. Our findings are in line with recent studies that highlight how poorly maintained AC systems and inadequate ventilation can exacerbate respiratory conditions, particularly in occupational settings. For example, Yang et al. (2019) found that individuals with pre-existing respiratory conditions, such as asthma or COPD, were more vulnerable to adverse effects of AC exposure, especially in environments where AC systems were poorly maintained. (15) This is consistent with our findings, where long-term AC users exhibited significant impairments in FVC and FEF25-75%, signaling early signs of restrictive lung disease. Zhuang et al. (2020) also emphasized the importance of AC filtration in maintaining indoor air quality and reducing the circulation of harmful particles. (16) Our study supports this, as participants exposed to poorly filtered AC systems experienced more significant reductions in lung function compared to those in better-maintained environments. Furthermore, Wang et al. (2021) found that indoor humidity control played a critical role in improving pulmonary outcomes, with higher humidity levels correlating with better lung function, suggesting that the combination of cool, dry air and poor filtration in AC systems may worsen respiratory health. (17)

The differences in pulmonary function between AC users and non-users can be attributed to several factors. Air conditioning systems, especially when poorly maintained, can circulate allergens, dust, and other particles that trigger respiratory symptoms, contributing to lung function decline. Additionally, the cool, dry air from AC units may irritate the airways, particularly for those exposed over long periods. These environmental factors could explain the reductions in lung volumes and mid-range expiratory flow rates observed in AC users. Our findings align with research by Seppänen et al. (14) and Huang et al. (6), which also noted the respiratory risks associated with poor indoor air quality in air-conditioned spaces. In summary, the discrepancies between our findings and those of previous studies likely stem from differences in study design, participant characteristics, and the quality of AC systems. Our research focused on long-term AC users, which may have intensified the adverse effects on lung volumes and expiratory flow rates. Further research is needed to better understand these effects and explore interventions such as improved AC maintenance or enhanced air quality controls to mitigate the respiratory risks of AC exposure. Individuals frequently exposed to AC, especially in occupational settings, should be monitored for early signs of respiratory dysfunction and provided with appropriate preventive measures to protect their lung health.

Table 3 Comparative Analysis of Results

My Study Conclusion	Similar Study	Dissimilar Study	Justification for Dissimilarity in Our Study
Significant reduction in predicted FVC among AC users compared to non-AC users.	Similar findings reported by Hulke et al. (11) and Al-Hazmi et al. (3), who also observed reductions in FVC among individuals with prolonged AC exposure.	Tanaka et al. (2) reported no significant differences in FVC between AC users and non-users.	The discrepancy may be due to differences in the duration and intensity of AC exposure. In our study, participants had prolonged and consistent exposure (more than six hours per day for at least one year).
No significant reduction in FEV1 between AC users and non-AC users.	Similar findings reported by Tanaka et al. (2), showing minimal impact of AC use on FEV1.	Hulke et al. (11) reported significant reductions in FEV1 among AC users.	Differences in baseline health conditions and AC exposure levels in Hulke's sample may explain the variance in findings.
Significant reduction in PEFR and FEF25-75% among AC users.	Jacobs et al. (4) and Yoon et al. (5) also reported reductions in small airway function among AC users.	Seppänen O (14) et al. found no significant differences in PEFR and FEF25-75% between AC users and non-users.	The difference could be attributed to the quality of AC systems; Seppänen O et al. focused on well-maintained environments with advanced ventilation, unlike our study which included individuals in environments with substandard AC maintenance.
No significant differences in FEV1/FVC ratio between AC users and non-users.	Similar results were observed by Jacobs et al. (4) and Yoon et al., (5) showing no significant difference in FEV1/FVC ratio.	Studies by Hulke et al. (11) showed significant differences in FEV1/FVC ratio between AC users and non-users.	Differences may be due to variations in sample health conditions or the quality of AC systems used.
AC exposure appears to reduce small airway function based on FEF25-75%.	Zhuang et al. (16) also reported reductions in small airway function among AC users, supporting our findings.	Seppänen O (14) et al. found no significant reductions in small airway function related to AC use.	The quality of AC maintenance could explain the differing findings, with better-maintained systems causing fewer issues.
Well-maintained AC units may reduce respiratory symptoms by improving air filtration.	Wang et al. (17) observed that well-maintained AC systems improved air quality and reduced the incidence of respiratory symptoms.	-	-

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