Diagnostic Value of Forced Vital Capacity in identifying Respiratory Compromise in Cancer Patients

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Abstract

This study examined the relationship between demographic factors, smoking behaviour, body mass index (BMI), and forced vital capacity (FVC) in a sample of 153 adults. Spirometric assessment was conducted using three repeated FVC measurements, and the average value was used for analysis. Descriptive statistics showed that most participants were young, male, and non-smokers. Mean FVC was higher in males compared with females, and a decline in FVC was observed with increasing age. One-way ANOVA indicated significant differences in FVC across smoking categories, although these differences were not significant after adjusting for age, gender, and BMI in the multivariable model. Regression analysis demonstrated that age and gender were the strongest predictors of FVC, while BMI and smoking status showed limited independent effects. The reliability of repeated FVC measurements was high, indicating strong consistency within the testing process. These findings suggest that pulmonary capacity in this population is primarily influenced by intrinsic factors such as ageing and sex, and that routine spirometric screening may be valuable for identifying individuals at risk of reduced respiratory function.

Keywords: forced vital capacity, spirometry, smoking, demographic factors, lung function

Introduction

Respiratory function is a vital component of health and may be compromised in patients with cancer due to factors associated both with the disease and the treatments directed at it, which can ultimately limit lung volume [1]. Several metrics exist to assess lung function, but one of the most important is the FVC (Forced Vital Capacity), which is the maximum volume of air exhaled from the point of maximal inhalation [2]. FVC-based monitoring of respiratory compromise in patients with cancer has proven to be an essential component during the course of care and not only aids in the identification of pulmonary dysfunction at an early stage, but also in the assessment of dynamics with time in return of respiratory health following treatment/ during the course of illness [3].

Respiratory dysfunction due to cancer is frequently multifactorial, caused by a combination of tumour burden, direct invasion of thoracic or diaphragmatic structures or indirect systemic effects of the disease mediated by immunological and paraneoplastic mechanisms [4]. Moreover, side effects of different therapies such as chemotherapy, radiotherapy, and immunotherapy may also promote respiratory difficulties [5]. Because of this intricate array of factors, diagnosing and monitoring any respiratory condition is essential in providing holistic care for cancer patients. In this context, FVC emerges as a relatively simple and powerful metric potentially revealing information on respiratory capacity and prognosis [6].

Evolving evidence have progressively highlighted the relevance of lung health stands in the care of patients with cancer [7, 8]. Several studies have demonstrated that the impairment of lung function, especially FVC, may result in lower physical tolerance and quality of life and increased susceptibility to infections, which can negatively affect cancer outcomes [9]. As a result, FVC measurements should be integrated into routine clinical assessments of cancer patients so that their health status can be comprehensively assessed, thereby allowing timely interventions to reduce respiratory decline.

Although FVC is of clinical importance, it has been underappreciated in the diagnosis and management of cancer [10]. Every so often, the spotlight is on direct management of the cancer, with less importance on secondary health concerns such as respiratory function [11]. However, as cancer therapies have become more aggressive and have become more individualized, the risk of respiratory complications is higher, demanding a pre-emptive approach [11]. This also underlines the importance of regular assessment of pulmonary function, through particularly non-invasive, simple to use techniques such as spirometry, in which the forced vital capacity (FVC) is an important parameter in the assessment process.

Overall, compromised lung function diminishes the effectiveness of cancer treatment and is especially detrimental to treatment of lung or non-lung thoracic cancers [12]. An inadequate pulmonary status may however at times skew the risk-benefit ratio of various treatment options, limiting treatment modalities, further complicating the patient's prognosis [13]. This is a crucial use of FVC testing as it allows for timely accomplishment by clinicians if respiratory impairment occurs and they can modify or implement therapies whilst safeguarding lung function to ensure that the effectiveness of the cancer treatment is not compromised.

Moreover, multiple recent analyses have focused on the association between FVC and long-term existence in cancer patients [9, 14]. Reduced FVC has been associated with higher rates of post-operative complications in patients undergoing surgery for cancer, as well as poorer outcomes in those receiving radiotherapy [15, 16]. In this respect, FVC is the most important variable, and we recommend its use not only for diagnostic purposes, but maybe even for prognostic value and potentially assisting clinicians to a risk-based tailored management of their patients [17].

The efficiency of FVC testing outspreads beyond lung-specific cancers [18]. Breast cancer, lymphoma and leukaemia are all examples of systemic malignancies for which treatment can affect lung function [19]. Thus, in these scenarios, regular assessment of FVC may serve as an early marker of potential pulmonary side effects and allow for timely modification of treatment protocols or initiation of pulmonary rehabilitation and respiratory exercise. These have been demonstrated to enhance outcomes in cancer patients with compromised pulmonary function [20].

Additionally, understanding how FVC varies among different cancer subtypes and treatment modalities can provide valuable insights into tailoring supportive care. For instance, cancer patients undergoing radiotherapy in the thoracic region are at a higher risk of radiation pneumonitis, which can dramatically decrease lung capacity [21]. Regular FVC measurements in these patients allow for early detection of respiratory compromise, potentially preventing more severe complications [22].

Also, knowing the variation of FVC in cancer treatment pathways is important as it will help in personalized supportive care and opens the door for interdisciplinary association between oncologists, pulmonologists, and rehabilitation specialists [23]. This collective management guarantees that the respiratory health of cancer patients is not overseen and that proactive actions are appropriated to improve lung function throughout the cancer treatment continuum. Such interdisciplinary endeavors can drastically enrich the patient outcomes and quality of life [24].

Therefore, this study aims to systematically evaluate the FVC in cancer patients with the anticipation that these parameters might help to characterize the severity of respiratory compromise associated with cancer and its treatment modalities. These findings in this research will provide an evidence for the use of FVC as a diagnostic and prognostic tool, enriching the capability of the clinicians to supervise the respiratory health in cancer patients, personalize treatments, thereby enhancing their patient outcomes and improving their quality of life

2. Materials and Methods

2.1. Study Design, Settings, Patients:

This cross-sectional study was carried out in the Out-patient Physical Therapy Department at King Khalid University, Kingdom of Saudi Arabia, from June 2022 to September 2024. The study received approval from the University Ethics Committee (ECM #2023-7124) and was conducted in full accordance with the ethical principles of the Declaration of Helsinki.

2.2. Subjects:

A total of 153 patients from the university hospital, who had been diagnosed with cancer following a comprehensive screening by an oncology specialist, were referred to the Physical Therapy Out-patient Department. The general characteristics of all participants, including body weight, height, BMI, past medical history, surgical history, family history, and spirometry results, were assessed. All participants provided written informed consent prior to their involvement in the study.

Procedure:

During the assessment session, each participant was instructed on how to use the handheld spirometry device. After receiving guidance, the participant positioned the mouthpiece securely and inhaled deeply before performing a forceful, sustained exhalation into the device, as demonstrated in the photograph. The procedure was performed while seated in a comfortable position to ensure stability and proper technique. Each participant completed three maximal efforts with rest intervals between attempts, and the average value was used for analysis. The demonstration shown reflects the typical posture and method used during data collection (Figure 1).

Figure 1. Demonstration of the spirometry testing procedure used in the study.

Data Analysis:

The dataset was analysed using SPSS (Version 28.0) for statistical analysis. Descriptive statistics (mean ± standard deviation) were used to summarise continuous variables such as age, BMI, and Forced Vital Capacity (FVC) values, while categorical variables (e.g., gender, smoking status) were summarised using frequency and percentage distributions. Data were checked for normality using the Shapiro-Wilk test and histograms; for all continuous variables, the assumption of normality was met.

Demographics & Grouping Variables:

The sample was divided by demographic factors, including age group, gender, nationality, and marital status. For categorical variables like smoking status (non-smoker, cigarette smoker, and cigar/pipe smoker), chi-square tests were performed to test the associations with other demographic characteristics. For continuous variables like FVC, independent samples t-tests were used to compare groups (e.g., male vs female).

Statistical Procedures:

Descriptive statistics: The first step in the analysis was to describe the sociodemographic characteristics of the participants. The mean, standard deviation, and percentages were reported for continuous and categorical variables. This step helped outline the baseline characteristics of the sample population.

Comparison of groups:

For continuous variables (e.g., FVC), independent-samples t-tests and one-way ANOVA were performed to compare means across different categories (e.g., males vs. females, smokers vs. non-smokers).

For categorical variables, chi-square tests were used to examine the relationships between smoking status and other sociodemographic factors.

Regression analysis:
To identify predictors of FVC, a multiple linear regression analysis was conducted using the following predictors: age, gender, BMI category, and smoking status. The dependent variable was the Average FVC score (the mean value across three measurements). The results of the regression analysis provide insight into the key factors associated with lung function in the sample.

Post-hoc tests and interaction effects:
For the one-way ANOVA that examined differences in FVC between smoking categories, Tukey's HSD post-hoc procedure was conducted to determine which specific smoking groups differed from one another. In addition, possible interaction effects between age and gender on FVC were explored by introducing interaction terms into the multiple linear regression model. This approach was used to determine whether the combined influence of age and gender contributed significantly to variations in FVC values.

Normality checks and outlier handling:

Normality of continuous variables was tested using the Shapiro-Wilk test and was further inspected through visual examination of histograms. Boxplots were used to identify potential outliers in the FVC measurements. When an outlier was detected, the value was reviewed to determine whether it resulted from measurement or data entry error. Depending on the influence of the outlier on the analysis, it was either excluded or winsorised to reduce its impact while retaining the integrity of the dataset.

Statistical significance:

Statistical significance was defined as $p < 0.05$. All analyses were interpreted using a 95 percent confidence level. For regression models, adjusted R-squared values were calculated to quantify the proportion of variance in FVC explained by the predictors. Variance Inflation Factor (VIF) values were examined to ensure that multicollinearity among predictors was not present, allowing for accurate estimation of regression coefficients.

Figures used in the manuscript were generated through SPSS for bar charts and boxplots, while scatterplots with fitted regression lines were produced using Matplotlib in Python to provide clear visualisation of the relationship between age and FVC.

Tables

Table 1. Sociodemographic characteristics

Variable	Category	n	%
Gender	Male	120	78.4
Gender	Female	33	21.6

Table 2. Clinical and smoking-related characteristics

Variable	Category	n	%
Chest disease	Yes	21	13.7
Chest disease	No	132	86.3

Figure 1: Distribution of smoking status

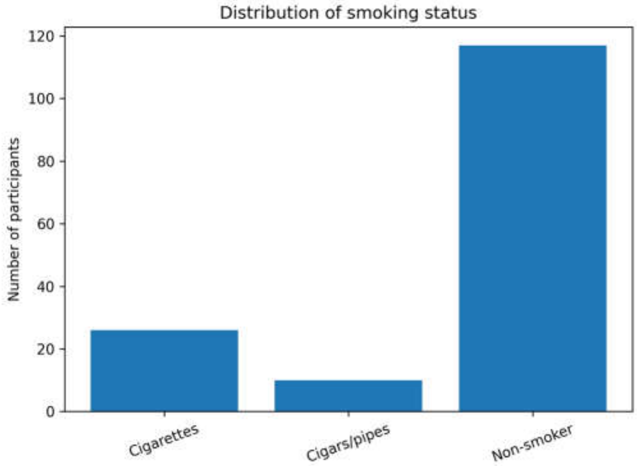


Figure 2: Average FVC according to gender

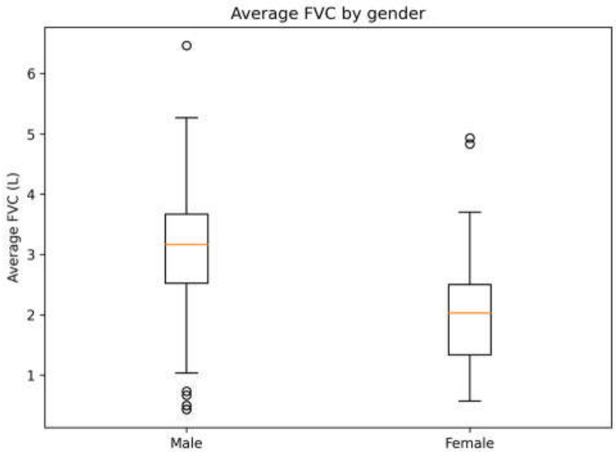
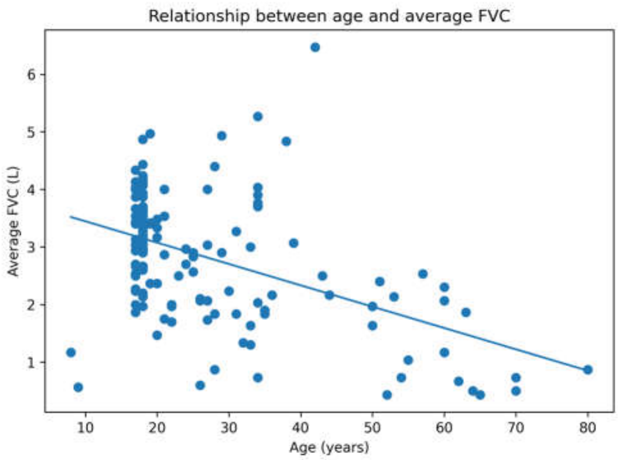


Figure 3: Relationship between age and average FVC



RESULTS

Sample characteristics

A total of 153 participants were included in the study. Most were male (78.4 percent) and Saudi nationals (90.8 percent). The majority were aged 39 years or younger (85.6 percent), while only 7.2 percent were aged 60 years or above. About three-quarters of the sample were single (73.9 percent), and 73.2 percent had completed pre-university education, whereas 24.8 percent held a bachelor's degree.

The mean BMI of the sample fell within the overweight category. When BMI was classified, 36.6 percent were normal weight, 24.2 percent were overweight, 24.8 percent were obese, and 14.4 percent were underweight.

Clinical and smoking-related characteristics

A total of 13.7 percent of participants reported having a chest-related disease, whereas diagnosed tuberculosis was very uncommon (0.7 percent). A family history of lung cancer among first-degree relatives was reported by 2.6 percent of the sample.

Exposure to passive smoking was relatively frequent, with 30.7 percent reporting regular exposure. Regarding active smoking behaviour, 76.5 percent were identified as non-smokers, 17.0 percent as cigarette smokers, and 6.5 percent as cigar or pipe smokers.

Spirometric performance and repeatability

The mean average FVC for the sample was 2.83 ± 1.10 litres. The three individual FVC attempts ranged from 2.76 to 2.91 litres, with the third attempt showing a slightly higher value. FVC values were consistently higher among males, whose mean average FVC was 3.05 ± 1.01 litres, compared with 2.03 ± 1.06 litres in females.

The reliability of the three FVC attempts was high, with a Cronbach's alpha of 0.94, indicating strong within-session repeatability of the spirometric measurements.

FVC according to smoking, BMI and age

When average FVC was compared across smoking categories, cigarette smokers had the highest mean value (3.07 ± 0.93 litres), followed by non-smokers (2.86 ± 1.11 litres), while cigar or pipe smokers recorded the lowest mean value (1.93 ± 1.09 litres). A one-way ANOVA confirmed a statistically significant difference in FVC across smoking groups ($F = 4.13$, $p = 0.018$).

Average FVC varied with BMI and age. Younger individuals, particularly those aged 39 years or below, tended to have higher FVC values across BMI categories. In contrast, older individuals, especially those aged 60 years or more, generally showed lower FVC values, most noticeably in overweight and obese categories. One overweight participant aged 40–49 years recorded an unusually high FVC value of approximately 6.5 litres, representing a clear outlier.

The scatterplot displaying age against average FVC demonstrated a negative relationship, with FVC decreasing progressively as age increased.

Multivariable predictors of FVC

Multiple linear regression analysis showed that age and gender were significant predictors of average FVC. Each additional year of age was associated with a decrease of 0.032 litres in FVC, while being male was associated with an increase of approximately 0.75 litres compared with females.

BMI category did not show a significant independent effect on FVC after adjustment ($p = 0.94$). Similarly, smoking categories did not significantly influence FVC when age, gender, and BMI were controlled for, with both cigarette smoking and cigar or pipe smoking showing non-significant associations (p values greater than 0.36).

Overall, the findings indicate that pulmonary capacity in this sample is primarily influenced by age and sex. The effects of smoking status and BMI on FVC appear to be less substantial once these dominant factors are taken into account.

Discussion

The present study evaluated respiratory function, demographic characteristics, and smoking-related factors among a sample of adults using spirometric assessment of forced vital capacity (FVC). The findings showed that age and gender were the strongest predictors of FVC, while smoking status and BMI demonstrated weaker associations after adjusting for major covariates. These results are consistent with existing physiological knowledge about lung development, ageing, and sex-related anatomical differences.

The study population was predominantly male, young, and of Saudi nationality, which may partly explain the relatively high average FVC observed in most participants. The higher FVC values among males compared with females align with well-established differences in thoracic dimensions, airway diameter, and lung volume between the sexes. Male participants consistently demonstrated higher FVC in all three spirometry attempts, reinforcing the robustness of this pattern.

A progressive decline in FVC with advancing age was observed, and this trend was further confirmed in the regression model [25]. This is consistent with prior evidence showing that lung elasticity, chest wall compliance, and respiratory muscle strength gradually diminish with age. The scatterplot also demonstrated a clear downward trend, indicating that age-linked reductions in pulmonary function begin relatively early and continue across the lifespan [26].

Although smoking is widely recognised as a major risk factor affecting lung function, the findings in this study suggest that, after controlling for age and gender, smoking status did not significantly influence FVC [27]. One explanation may be the relatively young age of the sample and the predominance of non-smokers [28]. Another possibility is that cumulative exposure (pack-years) was not captured, which may limit the ability to detect smoking-related impairment. Nevertheless, the ANOVA indicated significant differences across smoking categories at the unadjusted level, suggesting that smoking may play a role but less prominently than age or sex in this specific sample.

BMI was not a significant predictor in the multivariable model, although descriptive patterns indicated that extreme BMI values may influence FVC. Lower FVC in older overweight and obese individuals could be related to mechanical restrictions of the chest wall or reduced diaphragmatic excursion, but the lack of statistical significance suggests that BMI alone may not be a strong determinant in this dataset. The presence of a single outlier with exceptionally high FVC in the overweight group highlights the importance of individual variation and the need for cautious interpretation [29].

The high reliability of the three spirometry attempts, demonstrated by a Cronbach's alpha of 0.94, indicates excellent repeatability and supports the validity of the spirometric measurements obtained. This reinforces confidence in the accuracy of the FVC values and strengthens the interpretability of the findings.

Overall, the results suggest that pulmonary capacity in this population is primarily influenced by intrinsic factors such as age and sex, whereas lifestyle or health-related factors such as smoking or BMI show weaker or inconsistent associations. These findings highlight the need for targeted screening of individuals at risk of age-related pulmonary decline, as well as for further exploration of the long-term effects of smoking in cohorts with greater variability in age and smoking exposure.

Future studies could benefit from including pack-year quantification, occupational exposures, environmental pollutants, and physical activity levels, all of which are known to impact lung function. Additionally, larger samples with more balanced distributions across gender and age groups would improve the precision and generalisability of the findings. Longitudinal research may also help determine how early changes in FVC predict later respiratory impairment or disease.

Conclusion

This study examined forced vital capacity in relation to demographic factors, smoking behaviour, and BMI among a group of adult participants. The findings indicate that age and gender are the most influential determinants of lung capacity, with males demonstrating higher FVC values and increasing age associated with a steady decline in respiratory function. Smoking status and BMI showed limited independent effects once major predictors were controlled, although descriptive patterns suggest that these factors may still play a role in certain subgroups. The consistently high reliability of repeated FVC measurements supports the quality of the spirometric data. Overall, the results highlight the importance of early monitoring of pulmonary function, particularly in older adults and females who may be at higher risk of reduced respiratory capacity.

Several limitations should be considered when interpreting the findings of this study. The sample was predominantly young and male, which may limit the generalisability of the results to older populations or to groups with a more balanced gender distribution. The cross-sectional design prevents any causal inferences regarding changes in lung function over time. Smoking exposure was assessed using categorical classification rather than quantitative pack-year measurements, which may have reduced the ability to detect subtle effects of smoking intensity or duration.

Implications for practice

The results of this study have several implications for clinical and public health practice. Routine spirometric assessment may be beneficial for identifying individuals with early reductions in lung capacity, especially older adults and females who were shown to have lower FVC values. Health practitioners should be aware that lung function decline begins earlier than often appreciated and may progress even in the absence of overt respiratory symptoms. BMI did not show a strong association with FVC in this sample, but weight management should still be encouraged because obesity may contribute to respiratory strain and reduced physical endurance. The high reliability of FVC measurements in this study supports the use of standardised spirometry as a dependable tool in screening and monitoring respiratory health. Incorporating these findings into community health programs, workplace screenings, and preventive care strategies may help in early identification of individuals at risk for respiratory compromise.

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