The Factors Associated with Lung Cancer Screening by Low-dose Computerized Tomography

by

Siddhi Chovateeya

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This is to certify that the Master's Thesis of

Siddhi Chovateeya

has met the thesis requirements

for the degree of

Master of Public Health

Approved by:

Marshare Penny

Marshare Penny, DrPH, MPH
Professor
Committee Chair

Ashley V. Parks

Ashley Parks, DrPH, MPH, MCHES
Associate Professor
Committee Member

Lindsay Fahnestock

Lindsay Fahnestock, DrPH, MPH
Assistant Professor
Committee Member

Abstract

Introduction. Lung cancer screening with low-dose computerized tomography (LDCT) is an effective and important tool to diagnose and reduce the chances of co-morbidities and lung cancer deaths. The aim of this study was to examine if any relationship exists between LDCT, chronic obstructive pulmonary disease (COPD), smoking behavior, and influenza vaccination among people between the ages of 18 to 64 years and 65 years or older. **Method.** A cross-sectional research design was used in this study. A stratified random sampling method was used. The sample had 192 participants who responded to the Behavioral Risk Factors Surveillance System (BRFSS), which was used to measure participants' responses on LDCT, COPD, smoking behavior, and influenza vaccination. Descriptive statistics, a Chi-square test of independence, and Cochran-Mantel-Haenszel test (CMH) were calculated to find relationship between these variables. **Results.** There was a statistically significant association found between chronic obstructive pulmonary disease and low-dose computerized tomography ($x^2(1) = 8.52$, $p = 0.004$). Among those who received an influenza vaccination, a statistically significant result was found between the relationship of chronic obstructive pulmonary disease and low-dose computerized tomography ($x^2(1) = 7.39$, $p = 0.007$). However, the results suggest that LDCT may not have an influence on smoking behavior. **Discussion.** Participants who undergo LDCT screening are more likely to report chronic obstructive pulmonary disease. The future research should be focused on proving a causal relationship between these variables through longitudinal or randomized controlled trial studies.

Keywords: LDCT, COPD, smoking behavior, influenza vaccination

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Introduction

Lung cancer is an invasive and heterogenous disease, or a medical condition that has more than one etiology or cause (Berg, Doremalen, Vaduganathan, & Fauci, 2011). It is the second most common cancer in males and females after prostate cancer and breast cancer, respectively (American Cancer Society, 2018). Many advances in surgical, chemotherapeutic, and radiotherapeutic methods have been made, but the long-term survival rate of lung cancer patients remains low (Berg et al., 2011). Lung cancer mainly occurs in older people, and most people diagnosed with it are 65 or older (Siegel et al., 2014). Lung cancer is the leading cause of cancer death, making up almost 25% of all cancer deaths nationwide (American Cancer Society, 2018). In 2019, the lifetime risk of developing lung cancer was 6.7% for males and 5.9% for females of the United States (Moyer, 2014). According to the American Cancer society (2018), more than 228,000 new cases and 135,000 deaths due to lung cancer are expected by 2020.

There are many risk factors associated with lung cancer such as smoking, age, gender, radon exposure, occupational hazards, air pollution, and any pre-existing lung disease or compromised immune system (de Groot & Munden, 2012). Due to its high level of severity and impact on the older population, it is important to understand the underlying causes of this disease. Further, understanding the underlying causes may extend the lives of the people who develop lung cancer by guiding them to a lifesaving intervention.

Overview of Literature

As lung cancer becomes more prevalent in high risk population or adults, it is important to recognize the factors that can increase the chance of overall survival. Lung cancer screening with low-dose computerized tomography (LDCT) is the only recommended test for people who have no symptoms of lung cancer but are at high risk and can decrease the chances of co-morbidities and mortality (Centers for Disease Control and Prevention [CDC], 2020). The following literature will explain the underlaying factors that affect the lung cancer screening procedures with LDCT such as, Chronic Obstructive Pulmonary Disease (COPD), smoking behavior, and influenza vaccination and also explain its impact on the outcomes of the disease progression and treatment.

Lung Cancer and Screening

Lung cancer screening is an effective and important tool to diagnose and reduce lung cancer deaths. The United States Preventative Service Task Force (USPSTF) recommends lung cancer screening with LDCT in adults aged 55 to 80 years with a history of smoking (Tanoue et al., 2015). Results from National Lung Screening Trial (NLST) showed that annual screening with low-dose computerized tomography in a high-risk population was able to reduce 20% mortality due to lung cancer as compared to conventional chest radiography (CXR) or sputum cytology (SC) (Chudgar et al., 2015). Both policy level and clinical level LDCT have some potential risks over the benefits of reducing cancer mortality (Tanoue et al., 2015). The guidelines from National Lung Screening Trial are established to identify an appropriate screening population and develop national standards for radiological testing in a high-risk population (Nanavaty, Alvarez, & Alberts, 2014). Potential benefits due to early detection include reduced lung cancer mortality, improved quality of life, and identification of any other serious health issues (Moyer, 2014). However, lung cancer screening was reported to reduce quality of life in patients who had an unfavorable response towards screening and also reduced their life expectancy by 10 years regardless of screening procedures successfulness (Moyer, 2014).

Chronic Obstructive Pulmonary Disease

COPD refers to group of diseases that causes airflow blockage and breathing related problems in older people (CDC, 2020). Around 65 million people worldwide have moderate to severe COPD, and 24 million people around the U.S. are currently suffering from some form of COPD but only half of them are diagnosed (Martin, 2020). Furthermore, more than 800,000 hospitalizations each year in the U.S. are associated with COPD, which is a serious consequence of other respiratory illnesses (Martin, 2020). There are many risk factors that increase an individual’s vulnerability to this disease, such as tobacco consumption, bronchitis, asthma, systemic inflammation, pathophysiological condition, genetic predisposition, and lung cancer (Tyl & Domagała-Kulawik, 2017).

COPD and Pulmonary Emphysema are considered leading risk factors for lung cancer development in smokers rather than non-smokers (Mouronte-Roibás et al., 2016). Patients with a confirmed diagnosis of COPD have a 6 to 13 times higher risk of developing lung cancer than healthy individuals (Mark, Kargl, Busch, Yang, Metz, Zhang, & Houghton, 2018). Consequently, COPD is often the first cause of death in lung cancer patients. Additionally, the similarity of the clinical picture of lung cancer and COPD causes many problems for proper diagnosis and implementation of treatment (Tyl & Domagała-Kulawik, 2017). COPD impacts the development and prognosis of lung cancer; therefore, their conflicting results have not been understood as of yet (Dai, Yang, Cox, & Jiang, 2017). It is also evident that the majority of patients with COPD are diagnosed with lung cancer; thus, the comorbidity of these two diseases influences the treatment and screening procedures for lung cancer patients (Tyl & Domagała-Kulawik, 2017). In the U.S., more than 30% of cases of COPD are diagnosed among current smokers aged 65 years or older (Elflein, 2019). Hence, it has become a higher priority for researchers to understand the association between COPD, pulmonary emphysema, lung cancer, and tobacco-related illnesses as it may lead to improvements in lung cancer screening programs and decrease in the co-morbidities (Seijo et al., 2017).

In the study by Du and colleagues (2020), it was suggested that LDCT imaging is able to reduce the number of unnecessary referrals of early-diagnosed lung nodules (25%) and improve the early detection of COPD in lung cancer patients. On the aspect of survival advantage, the results from a Danish Lung Cancer Screening Trial showed favorable effects of screening procedures in lung cancer mortality in COPD patients (Wille, Dirksen, Ashraf, Saghir, Bach, Brodersen, & Skov, 2016). There are several aspects to be considered during implementation of lung cancer screening measures among COPD patients, such as underdiagnosed or misdiagnosed COPD, other risk assessments like age and body mass index (BMI), over-diagnosed lung nodules, and mortality and morbidity rates. According to the study by de Torres and colleagues (2013), lung cancer screening may contribute to a higher detection rate (12.5%) of chronic obstructive pulmonary diseases and early diagnosis of lung cancer while minimizing over-diagnosis. Additionally, the results of NLST show that COPD patients screened for lung cancer have lower mortality rate than the patients who are not screened (15% and 28%, respectively) (de Torres et al., 2013).

Smoking Behavior

Smoking is the second leading risk factor for global disease burden and causes more than six million deaths annually around the world (Lim et al., 2012). More than 100,000 people become addicted to smoking or tobacco consumption every day (Ritchie & Roser, 2013). Cigarette smoking is also associated with the development of chronic lung diseases, lung cancer, coronary heart diseases, cerebrovascular diseases, anxiety, pneumonia, and type 2 diabetes in older people (Davies et al., 2020). It is generally considered a primary risk factor for COPD; however, the mechanism behind this remains unknown (Lim et al., 2012). The U.S. Medicaid program spends more than $39 billion in healthcare costs for smoking-related diseases each year, which is more than 15% of total Medicaid spending (American Lung Association, 2020). Smoking costs the U.S. economy over $332 billion in direct healthcare costs and lost productivity each year (American Lung Association, 2020). Many tobacco cessations programs exist; however, lung cancer and chronic disease screening may also help reduce mortality due to tobacco consumption (Kakinuma, Muramatsu, Asamura, Watanabe, Kusumoto, Tsuchida, & Moriyama, 2020).

More than 85% of COPD cases and 90% of lung cancer cases are caused by tobacco consumption or smoking (American Lung Association, 2020). On average, smokers lose 15 years of life and experience premature death as compared to non-smokers (World Health Organization [WHO], 2016). Lung cancer screening using LDCT reduces smoking-related cancer mortality; although, the effectiveness of the screening procedures is not fully established (Kakinuma et al., 2020). According to the National Lung Screening Trial recommendation, those who smoke more than 30 packs per year should be considered for lung cancer screening with LDCT (Tanoue et al., 2015). Yet, in the study by Kakinuma and colleagues (2020), it was found that a higher number of lung cancer cases were diagnosed in non-smokers or never-smokers (49.6%) rather than among smokers who smoke more than 30 pack per year (27.1%) and less than 30 pack per year (23.3%). Therefore, not every lung cancer patient meets the criteria of lung cancer screening with LDCT, regardless of smoking behavior.

In a study by Cao and colleagues (2020), it was suggested that implementation of lung cancer screening procedures (low-dose computerized tomography) along with smoking cessation programs could reduce lung cancer death rates by 14%. Lung cancer screening interventions have the potential to enhance the impact of smoking cessation programs (Cao et al., 2020). Consequently, lung cancer screening with LDCT reduces cancer-related mortality and changes smoking behavior in smokers.

Influenza Vaccine

Surgical resection is the primary lung cancer treatment, but the relapse rate after resection is more than 40% (Kelly & Giaccone, 2011). According to Freeman-Keller and colleagues (2015), patients with small-cell lung cancer (SCLC) and non-small cell lung cancer (NSCLC) have survival rates of 52.2%, while the patients with metastatic tumors have survival rates of 3.7%. Because of this, an understanding of tumor immunology should be encouraged in the generation of modern lung cancer vaccination.

Immunization with influenza and pneumococcal vaccines is generally considered to be useful. In the recent study by Gupta and colleagues (2013), administering influenza vaccine in COPD patients increased the chance of overall survival of lung cancer since it reduced the chance of secondary infection. A meta-analyses study showed that influenza vaccination reduced the number of exacerbations in patients of COPD, especially in patients with a severe disease, and also increased COPD diagnosis rate (Gupta et al., 2013). The study results also suggested that patients with chronic obstructive pulmonary diseases are more likely to receive influenza vaccinations (Gupta et al., 2013).

Influenza vaccination has proved least effective in decreasing influenza-associated hospitalization in patients with COPD (Gershon et al., 2019). According to Gershon and colleagues' study (2019), there is no association between influenza vaccination and COPD treatment in lung cancer patients. On the other hand, administration of a pneumococcal vaccine is a safer anti-cancer treatment and could reduce the cancer mortality in patients with chronic respiratory illnesses (Chiou et al., 2015). The minimal effectiveness of the influenza vaccine increases the need for better vaccine development and other preventative strategies for COPD patients (Gershon et al., 2019).

Summary

Lung cancer screening with low-dose computerized tomography (LDCT) has been proven successful in older age (55 to 80 years) patients. However, controversy surrounding its use exists due to its limitation in early age cancer detection (Tanoue et al., 2015). Patients with chronic obstructive pulmonary disease have a high risk of developing lung cancer. It has been proven that if patients with COPD are screened with LDCT, then they have a lower risk of developing lung cancer (Du et al., 2020). Additionally, research has shown that influenza vaccine injection among COPD patients can reduce the chance of lung cancer development and the secondary infection of other respiratory illnesses (Chen et al., 2019). Also, lung cancer screening interventions with low-dose computerized tomography have the potential to enhance the impact of smoking cessation programs and reduce individuals chances of becoming a smoker.

Purpose of the Study

Currently, a gap exists concerning the relationship between lung cancer screening with low-dose computerized tomography (LDCT), chronic obstructive pulmonary disease (COPD), smoking behavior, and the influenza vaccine. The epidemiology of lung cancer and chronic respiratory illnesses are crucial to understand the validity of the use of LDCT, vaccination, and therapeutic management of COPD. The aim of this study is to assess the relationship between LDCT, smoking behavior, COPD, and vaccination with the influenza vaccine.

Research Questions

The following research questions are addressed in this study:

1) Is low-dose computerized tomography associated with chronic obstructive pulmonary disease?

2) Does the influenza vaccine influence the relationship between low-dose computerized tomography and chronic obstructive pulmonary diseases?

3) Is low-dose computerized tomography related to smoking behavior?

Hypotheses

It is hypothesized that those who undergo low-dose computerized tomography screening are more likely to report chronic obstructive pulmonary diseases compared to those who do not undergo low-dose computerized tomography screening. Also, influenza vaccination does influence the relationship between lung cancer screening with low-dose computerized tomography and chronic obstructive pulmonary disease. It is also hypothesized that those who are screened for lung cancer with low-dose computerized tomography are more likely to be non-smokers compared those who are not screened.

Method

Research Design

This study used a cross-sectional design to measure the relationship between the lung cancer risk factors (COPD and smoking behavior) and protective factors (lung cancer screening and vaccination) among adults in the United States. This study used secondary data from the 2018 Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS dataset is the nation's premier system of health-related annual statewide random telephone and cellular surveillance survey designed by the CDC. It collects the state data about U.S. residents regarding their health-related risk behaviors, chronic health conditions, and use of preventive services (CDC, 2019). The BRFSS is a cross-sectional study survey conducted by all 50 states and the health departments in the District of Columbia, Guam, Puerto Rico, and the U.S. Virgin Islands.

Participants

The target population for this study included all adults ages 18 years and older randomly selected from the 2018 Behavioral Risk Factor Surveillance System (BRFSS) dataset. The original dataset included a total of 437,436 participants. The participants who responded to the questionnaires of low-dose computerized tomography (LDCT), chronic obstructive pulmonary disease (COPD), smoking behavior, and influenza vaccination were selected, and missing responses were excluded from the dataset. As a result, a total 13,706 participants responded to these questionnaires. The sample size necessary for this study was calculated using G* Power Software Version 3.1. Using G* Power, the parameters used were a statistical power of 0.80, an alpha coefficient of 0.05, and a moderate effect size of 0.30. As a result, a final sample size of 192 participants was the minimum required sample size to answer each research question.

Procedure

This study utilized secondary data from the 2018 BRFSS questionnaires (CDC, 2019). The BRFSS is a system of health-related telephone surveys (landline and cellphone) that collect data about U.S. residents. The questionnaires are administered each year by trained interviewers using random digit dialing of non-institutionalized U.S. adults (CDC, 2019). Interviews are conducted according to standard protocols, which verify data quality and confidentiality (Pickens, Pierannunzi, Garvin, & Town, 2018). BRFSS surveys have been collected in all 50 states, including union territories (Pickens et al., 2018).

The BRFSS questionnaire has three sections: a core section, optional modules, and state-added questions. This system has both open- and close-ended questionnaire and a skip pattern in open-ended questionnaires. There are a total of 17 core section questionnaires that address participants' self-reported health status, health care access, chronic health conditions, immunization, tobacco use, oral health, demographics, human immunodeficiency virus/acquired immunodeficiency virus (HIV/AIDS), and breast and cervical cancer screening (Pickens et al., 2018). In addition to this, 23 optional module questionnaires can be utilized and included; these cover sleep disorders, marijuana use, lung cancer screening, cancer survivorship, respiratory health, depression, and anxiety (Pickens et al., 2018). To address state specific needs, states can also add their own questions to the BRFSS (Pickens et al., 2018). The survey is provided in both Spanish and English by the CDC. This study utilized three core questions, one module question, and demographic questions.

The reliability and validity of the BRFSS core questionnaires of chronic health conditions, vaccination, and smoking behavior were recorded from moderate to excellent (Kappa = 0.60-0.75) (Pierannunzi, Hu, & Balluz, 2013). The reliability and validity of module questionnaires which includes low-dose computerized tomography were recorded as moderate (Kappa = 0.60) (Pierannunzi, Hu, & Balluz, 2013).

Independent Variables

The independent variables for this study include COPD, lung cancer screening LDCT, and influenza vaccinations. Lung cancer screening with LDCT was used as both an independent and dependent variable for separate research questions.

The first independent variable was COPD, from the first and second research questions, and was measured by the question C.06.08, *"Do you have chronic obstructive pulmonary disease, C.O.P.D., emphysema or chronic bronchitis?"* This variable in BRFSS dataset was recorded as a nominal variable with four levels, "1-Yes," "2-No," "7-Don't know/not sure," and "9-Refused." For the purpose of this study, COPD was recoded into a dichotomous categorical variable with two levels, "1-Yes," "2-No," and "7" and "9" were treated as missing values.

The second independent variable was LDCT, from the third research question, and was measured by the question M13.04, *"In the last 12 months, did you have a CT or CAT scan?"* LDCT in the BRFSS dataset was recorded as a nominal variable with five levels, "1-Yes," " 2-No," "3-Had a CT scan, but for some other reason," "7-Don't know/ Not sure," and "9-Refused." For the purpose of this study, LDCT was recoded into a dichotomous categorical variable with two levels, "1-Yes," "2-No," and "9-Don't know/Refused/Some other reason" which included "7-Don't know/Not sure," "9-Refused," and "3-Had a CT scan, but for some other reason" where responses labelled "9" were treated as missing values.

The third independent variable was influenza vaccination, from the second research question, and was measured by the question C11.01, *"During the past 12 months, have you had either a flu vaccine that was sprayed in your nose or a flu shot injected into your arm?"*

Influenza vaccination in the BRFSS dataset was recorded as nominal variable with four levels, “1-Yes,” “2-No,” “7-Don’t know/not sure,” and “9-Refused.” For the purpose of this study, influenza vaccination was recorded into a dichotomous categorical variable with two levels, “1-Yes,” “2-No,” and “7” and “9” were treated as missing values.

Dependent Variables

The dependent variables for this study were smoking behavior and lung cancer screening with LDCT. As described above, lung cancer screening with LDCT was used as both an independent and dependent variable for separate research questions.

The first dependent variable was smoking behavior, from the third research question, and was measured using the question C.09.02, *“Do you now smoke cigarettes every day, some days, or not at all?”* This variable in BRFSS dataset was recorded as a nominal variable with five levels “1-Every day,” “2-Some days,” “3-Not at all,” “7-Don’t know/ Not sure,” and “9-Refused.” For the purpose of this study, the smoking variable was recoded into a dichotomous categorical variable with “1-Every day,” which included “1-Every day” and “2-Some days,” and “2- Not at all.” The response options of “7-Don’t know/Not sure” and “9-Refused” were treated as missing values.

The second dependent variable, low-dose computerized tomography (LDCT) from the first and second research question, was measured using the question M13.04, *“In the last 12 months, did you have a CT or CAT scan?”* Low-dose computerized tomography in BRFSS dataset was recorded as nominal variable with five levels, “1- Yes”, “ 2- No”, “3- Had a CT scan, but for some other reason, “7-Don’t know/ Not sure”, and “9- Refused”. For the purpose of this study, low-dose computerized tomography was recoded into a dichotomous categorical variable with two levels, “1- Yes”, “2- No”, and “9- Don’t know/ Refused/ Some other reason” which includes 7- Don’t know/ Not sure, 9- Refused, and 3- Had a CT scan, but for some other reason, was treated as missing values.

Data Analysis

A Chi-square test of independence was performed to measure the relationship between COPD and lung cancer screening with LDCT. A Cochran-Mantel-Haenszel (CMH) test was performed to analyze whether influenza vaccination influences the relationship between COPD and LDCT screening. A Chi-square test of independence was also conducted to measure the relationship between lung cancer screening with LDCT and smoking behavior.

Results

Demographics

The sample in this study included data from the 2018 Behavioral Risk Factor Surveillance System (BRFSS). The aim was to explore the associations between LDCT screening and COPD as well as LDCT screening and smoking behavior. The majority of the study participants were male (54.7%). Upon examination of age group categories, 61.4% of participants were between 18 to 64 years old and 38.6% of participants were 65 years or older. Most of the BRFSS participants classified themselves as White Non-Hispanic (77.5%) followed by Hispanic (8.0%). Among the participants, 44.7% were married. Nearly 32% of study participants had graduated college, and most (90%) had, at minimum, a high school diploma (see Table 4).

Major Findings

For the first research question, a Chi-square test of independence was performed, exploring the relationship between COPD and LDCT screening. A statistically significant association was found between COPD and LDCT screening ($x^2(1) = 8.52$, $p = 0.004$). The odds of COPD were 3.62 times higher among those who underwent LDCT screening compared to those who did not undergo LDCT screening (see Table 1).

Table 1
Comparison of Chronic Obstructive Pulmonary Disease (COPD) and Low-dose Computerized Tomography (LDCT) (n=192)

Variable		LDCT		Adjusted OR
		Yes N (%)	No N (%)	(95% CI)
COPD				
	Yes	10 (5.2%)	26 (13.5%)	3.62* (1.47 - 8.91)
	No	15 (7.8%)	141 (73.4%)	

Note. N = Total Number, % = Valid Percent; OR, odd ratio; CI, confidence interval. Chi-square test was used to assess the relationship between low-dose computerized tomography and chronic obstructive pulmonary disease and low-dose computerized tomography. **p*=.004

For the second research question, a CMH Chi-square test was performed, exploring the potential that receiving an influence influenza vaccination may have on the relationship between COPD and LDCT screening. Among those who received an influenza vaccination, a statistically significant result was found between the relationship of COPD and LDCT screening ($x^2(1) = 7.39$, $p = 0.007$). Among those who did not receive an influenza vaccination, no statistically significant result was found between COPD and LDCT screening ($x^2(1) = 2.43$, $p = 0.119$). It appears influenza vaccinations influence the relationship between COPD and LDCT screening, but only among those vaccinated. Among the participants vaccinated for influenza, the odds of COPD were 6.57 times higher among those who received LDCT screening compared to those who did not received LDCT screening (see Table 2).

Table 2
Bivariate Association between Chronic Obstructive Pulmonary Disease (COPD) and Low-dose Computerized Tomography (LDCT) for Influenza Vaccine (n=192)

LDCT		Yes N (%)	No N (%)	Adjusted OR (95% CI)
Influenza Vaccine (Yes)	COPD (Yes)	5 (41.70)	7 (58.30)	6.57* (1.51 - 28.66)
	COPD (No)	5 (9.80)	46 (90.20)	
Influenza Vaccine (No)	COPD (Yes)	5 (20.80)	19 (79.20)	2.50 (0.77 - 8.15)
	COPD (No)	10 (9.50)	95 (90.50)	

Note. N = Total Number, % = Valid (Real) Percent, OR, odds ratio; CI, confidence interval. Chi-square test was used to assess the relationship between low- dose computerized tomography and chronic obstructive pulmonary disease for influenza vaccine. *p=.007 & p= 0.119

For the third research question, a Chi-square test of independence was performed, exploring the relationship between LDCT screening and smoking behavior (tobacco consumption). No statistically significant association was found between LDCT screening and smoking behavior among the participants ($x^2(1) = 0.01$, $p = 0.91$). Therefore, there is no association between LDCT screening and smoking behavior (see Table 3).

Table 3

Comparison of Low-dose Computerized Tomography (LDCT) and Smoking Behavior (Tobacco Consumption) (n=192)

Variable		Smoking Behavior		Adjusted OR (95% CI)
		Every day N (%)	Not at all N (%)	
LDCT				
	Yes	9 (4.7%)	16 (8.3%)	0.95 (0.39 – 2.28)
	No	62 (32.3%)	105 (54.7%)	

Note. N = Total Number, % = Valid Percent; OR, odd ratio; CI, confidence interval. Chi-square test was used to assess the relationship between low-dose computerized tomography and smoking behavior. p= 0.91

Discussion

The study analysis results revealed three major findings. Despite a few study limitations and inconsistencies, significant associations were found in two research questions that led to public health implications.

Summary of Major Findings

The results for the first research question indicate that there is a significant relationship between COPD and LDCT screening. These findings are consistent with the original hypothesis as well as consistent with de Torres' and colleagues' (2013) and Du and colleagues' (2020) findings. According to the study by de Torres and colleagues (2013), lung cancer screening contributes to a higher detection rate (12.5%) of COPD and early diagnosis of lung cancer while minimizing over-diagnosis. In the study by Du and colleagues (2020), it was suggested that LDCT imaging was able to reduce the total number of unnecessary referrals of early-diagnosed lung nodules up to 25% and improve the early detection of COPD in lung cancer patients. This further supports the notion that LDCT screening is helpful in the detection of COPD and the early diagnosis of lung cancer.

Findings for the second research question suggest that receiving an influenza vaccination influences the relationship between COPD and LDCT screening. Among the participants who received an influenza vaccination, a significant relationship was found between COPD and LDCT screening. These findings are consistent with the original hypothesis and consistent with the study by Gupta and colleagues (2013) in which it was found that COPD patients were more likely to be vaccinated against influenza. Their study also showed that influenza vaccination reduced the number of exacerbations in patients with COPD, especially in patients with severe COPD. However, this result is inconsistent with the study of Gershon and colleagues (2019) in which no association was found between influenza vaccination and COPD treatment. Their study also proved that the influenza vaccination is least effective in decreasing influenza-associated hospitalization in patients with COPD.

The results for the third research question found no significant association between LDCT screening and smoking behavior among the participants. These findings are inconsistent with the original hypotheses as well as the study by Cao and colleagues (2020) in which the implementation of lung cancer screening procedures along with smoking cessation programs were found to reduce lung cancer death rates by 14% due to a reduction in the number of smokers. Lung cancer screening using LDCT interventions have a potential to enhance the impact of smoking cessation programs and has been found to result in changes to smoking behaviors (Cao et al., 2020).

Public Health Implications

The current study's findings have some potential implications for program implementation and clinical practice. Increased respiratory diseases like COPD can lead to severe cases of lung cancer development (Du et al., 2020). Important areas to address include COPD surveillance, evaluation, research, and strategies to improve the understanding of COPD development, prevention, and treatment. Based on this research, healthcare providers should encourage lung cancer screening procedures in patients with COPD to delay lung cancer progression. For example, The U.S. Preventive Services Task Force recommends annual lung cancer screening with LDCT for persons who have a history of heavy smoking, smoke now or have quit within the past 15 years, and older people with COPD to delay or prevent lung cancer prevention (National Center for Chronic Disease Prevention and Health Promotion, 2020).

More than 75% of COPD cases are attributed to cigarette smoking; thus, COPD can largely be prevented by public health efforts aimed at smoking prevention and cessation (Cao et al., 2020). COPD is preventable and treatable but not curable. Therefore, public health programs and policies that focus on tobacco use/smoking prevention and cessation are critically important. Supporting collaboration between tobacco control and COPD programs to develop best practices and build templates for COPD action plans, including implementation strategies for programs, may improve prevention and intervention strategies. Newer policies should be applied to restrict smoking behavior among adults and the supply of cigarettes into the communities, which many ultimately reduce respiratory illnesses such as COPD and reduce lung cancer incidence. For example, supporting development of workplace policies, including indoor smoke-free and campus smoke-free policies, and providing strong worker and respiratory protection programs as well as resources for workplace screening programs for at-risk workers and families would be helpful to reduce respiratory illness.

Influenza vaccination plays an important role to reduce the severity of COPD. It has also been proven that the influenza vaccine is effective in preventing secondary complications and reducing the risk for influenza-related hospitalization and death among those with COPD (Gershon et al., 2019). Implementation of a successful vaccination program along with lung cancer screening by applying various strategies like patient reminder/recall systems and reducing administrative/financial barriers that prevent patients from getting vaccines will be extremely helpful to decrease influenza-related deaths in COPD patients. Increasing vaccine coverage by administrating influenza vaccines to COPD patients during hospitalization or routine healthcare visits/screening interventions would be helpful to reduce the rate of co-morbidities.

Additional research is needed to increase the evidence base for what can successfully increase the effects of LDCT screenings on the health outcomes of COPD and lung cancer patients. This additional evidence will facilitate public health efforts to address LDCT screenings as a primary intervention for lung cancer patients.

Study Strengths and Limitations

The strength of this study was the use of the BRFSS. The BRFSS measures have good reliability and validity. The reliability and validity of the BRFSS core questionnaires for chronic health conditions, vaccination, and smoking behavior were recorded from moderate to excellent (Kappa = 0.60-0.75) (Pierannunzi et al., 2013).

There are a few limitations to this study. One limitation was the small, stratified sample size. A stratified sampling method was applied to capture those who responded to the non-core BRFSS questions. This resulted in relatively small cell sizes, influencing the risk of a type I error. Other limitations include recall and self-report bias. The participants may have underreported or overreported their true screening procedures and smoking behavior, resulting in self-report bias. When completing the survey, participants were asked questions regarding past events. For example, participants were asked to remember their lung cancer screening procedures and diagnosis of COPD over the past twelve months. Participants may not have remembered their exact smoking habits and/or influenza vaccination practices in the past twelve months, resulting in recall bias when answering the questions of smoking habits and influenza vaccination.

The cross-sectional design used in this study was another limitation. Cross-sectional study designs are only able to examine the differences in groups using a snapshot in time. This study may have had different results if it were a longitudinal study measuring COPD, lung cancer screening, smoking behavior, and influenza vaccination. A prospective longitudinal study would better allow for the exploration of causal relationships between the study variables (Gershon et al., 2019).

Lastly, the external validity of the study was affected by characteristics of the sample. The sample consisted of 77.5% White Non- Hispanic/Latino, 8% Hispanic, 6.4% Black Non-Hispanic, 2.1% American Indian, 0.5% Asian Non-Hispanic, 2.1% Other Non-Hispanic, and 3.2% Multiracial Non-Hispanic. Additionally, 61.4% of participants were between the ages 18-64 years of age, followed by 38.6% of participants identified as age 65 years or older, resulting in a sample that was not generalizable. Therefore, research findings of this sample cannot be applied to the general population.

Future Directions

Future studies should continue examining the relationship between chronic obstructive pulmonary diseases, smoking behavior, and low-dose computerized tomography screening. The research should be focused on establishing a causal relationship between the variables by performing a longitudinal or randomized controlled trial. LDCT screening holds the potential to diagnose lung cancer and identify COPD cases in their initial or subclinical stage based on morphologic features of LDCT imaging. However, evidence on additive value for COPD diagnosis in LDCT is still limited, and more research is needed for further exploration of LDCT application. Also, minimally invasive and inexpensive tests are needed to identify individuals who have a high-risk of developing lung cancer and who are most likely to benefit from lung cancer screening. In COPD patients, the ability to diagnose between benign and malignant lung tumors will represent major advances in lung cancer screening. Moreover, recent studies regarding LDCT screening includes biomarker collection in COPD patient protocols, so new directions in this area can be expected in the future.

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Appendix: Demographics Table

Table 4

Participants Demographic Characteristics of 2018 BRFSS Sample (n = 192)

Demographic Variables	*n*	%
Gender		
Male	105	54.70
Female	87	45.30
Age		
Age 18-64 years	116	61.40
Age 65 years or older	73	38.60
Race/ Ethnicity		
White Non-Hispanic	145	77.50
Black Non-Hispanic	12	6.40
American Indian/ Alaskan Native Non-Hispanic	4	2.10
Asian Non-Hispanic	1	0.50
Other Race Non-Hispanic	4	2.10
Multiracial Non-Hispanic	6	3.20
Hispanic	15	8.00
Marital Status		
Married	85	44.70
Divorced	37	19.50
Widowed	23	12.10
Separated	6	3.20
Never Married	33	17.40

A Member of an unmarried couple	6	3.20
Education Level		
Never attended school	1	0.50
Elementary	9	4.70
Some high school	7	3.60
High school graduate	59	30.70
Some college/ technical school	55	28.60
College graduate	61	31.80

Note. n = Total Number and % = Valid Percent