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Racial Disparities in Occupational Risks and Lung Cancer Incidence: Analysis of the National Lung Screening Trial

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Contribution
HS Juon and J Barta conceptualized the study. A Hong and M Rojulpote did a literature review and wrote the introduction and discussion on the original draft. HS Juon devised the analysis plan conducted the analyses. J Barta, R McIntire, and M Pimpinelli reviewed and edited subsequent manuscript drafts. All authors edited the final draft of the article.

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ABSTRACT

The relationship between racial disparities in occupational risk and lung cancer diagnosis is not well defined. We examined occupational exposure to asbestos, silica, and other workplace chemicals, fumes, or dusts as reported in the National Lung Screening Trial (NLST). Descriptive analyses and multivariate logistic regression models were performed. Among the NLST study cohort, 3.9% were diagnosed with lung cancer. African-Americans had a higher rate of lung cancer diagnosis than White individuals (4.3% vs. 3.9%). About 28% reported at least one occupational exposure, including 6.5% exposed to silica and 4.7% to asbestos. African-Americans reported occupational exposure more frequently than White participants, including exposures to asbestos and silica. In a multivariate model, the interactions of all measures of occupational exposures and smoking status were significant. Current smokers with occupational exposures had higher odds of lung cancer diagnosis (aOR = 2.01, 95% CI = 1.76–2.30 for any exposure as well as higher odds after silica (aOR = 2.35, 95% CI = 1.89-2.91) or asbestos (aOR = 1.97, 95% CI = 1.52 -2.56) exposure compared to former smokers without any exposures. African-Americans had higher odds of lung cancer diagnosis than White individuals (aOR=1.24 to 1.25, 95% CI = 1.01-1.54). Our findings indicate that we need more effective public health prevention programs, especially for minorities who may have disproportionately greater occupational exposures due to socioeconomic constructs and barriers. Interventions may include education about occupational risks and lung cancer screening or instituting workplace policies for smoke-free environments with tobacco cessation support.

1. Introduction

Although lung cancer incidence and mortality rates have decreased in the past decade, lung cancer remains the leading cause of cancer-related death in the US for both men and women (American Cancer Society, 2018). Identifying individuals with high-risk lung cancer at an early stage of disease improves survival because it enables earlier and potentially curative treatment.

The major risk factor for lung cancer is cigarette smoking, with an attributable risk of at least 85% in the US (Jemal and Fedewa, 2017). However, smoking does not entirely explain lung carcinogenesis. Occupational exposures to workplace chemicals, fumes, and dusts have been correlated with lung cancer development (Liu et al., 2013). In particular, the association between asbestos exposure and lung cancer is well-established (Villeneuve et al., 2012; Markowitz, 2015). A meta-analysis of studies including the NLST demonstrated that low-dose CT (LDCT) screening in asbestos-exposed workers was effective in detecting asymptomatic lung cancers and that screening this population could reduce mortality for those exposed both to smoking and asbestos (Ollier et al., 2014). Working in coal gasification or an iron or steel foundry has been associated with increased lung cancer risk. Silica exposure, which is associated with the coal, hard rock mining, sandblasting, foundry or steel mining industries, is also associated with increased lung cancer risk, even after adjustment for smoking and second-hand smoke exposure (Liu et al., 2013; Kachuri et al., 2014).

Racial disparities in lung cancer are clearly delineated in the literature. Compared with White individuals, African-Americans are diagnosed at younger ages and more advanced stages of disease (Chu, Miller & Springfield, 2007). Although lung cancer incidence between 1973 and 2010 has declined among all racial groups, African-Americans continue to have higher relative incidence rates (Richards et al., 2017). Moreover, African-American patients are less likely to undergo surgical resection of early stage lung cancer and have lower 5-year survival rates than Whites (Shugarman et al., 2009; Coughlin et al., 2014). This greater lung cancer burden among African-Americans is due in part to differences in access to care, lower likelihood to accept surgical resection, and unsuccessful smoking cessation despite increased quit attempts compared to Whites (Richards et al., 2017). Racial disparities in lung cancer outcomes may also be partially explained by higher occupational exposure among minorities, particularly African-American men (Stewart, 2001). Historical and current socioeconomic constructs result in African-American workers being overrepresented in material-handling jobs, and they comprise a disproportionately large percentage of the workforce that is exposed to industrial carcinogens (U.S. Bureau of Labor Statistics, 2015; Swanson, Lin, & Burns, 1993).

A report of occupational exposures in 14 industries among NLST participants found that 38% of men and 14% of women reported occupational risks for at least one year in one or more of the industries (Aberle et al., 2010). The underlying causes of racial differences in lung cancer diagnosis and outcomes are unknown, and race-related environmental exposures remain poorly understood. To our knowledge, no study based on NLST data has assessed the effects of specific types of occupational exposures on lung cancer diagnosis. Analysis of occupational risks in conjunction with race can more clearly identify high-risk populations that need lung cancer screening. The purpose of this study is to examine the relationships of race, occupational exposures, smoking, and lung cancer burden in NLST data.

2. Methods

2.1. Data sources

The NLST study design has been described in detail previously (Aberle et al., 2010). Briefly, the study randomized 53,456 high risk participants on age and smoking history to either LDCT or chest radiography in equal proportion. Inclusion criteria were as follows: age 55 to 74 years and current or former smoker with at least a 30 pack-year history; former smokers had to have quit within the past 15 years. Annual screening by LDCT or chest radiography was offered to NLST participants for 3 years. The median follow-up time was 7 years. Approval for this project was obtained from the National Cancer Institute's Cancer Data Access System on October 16, 2017 (NLST-361).

2.2. Measures

Outcomes. Lung cancers were identified as pulmonary nodules and confirmed by diagnostic procedures. Lung cancer diagnosis was defined as the number of cases determined to have cancer during any of the three imaging points of intervention (and the remaining number of non-cancer patients), as well as post-screening cancer patients (i.e., those individuals who went on to develop lung cancer after the third screening event).

Occupational exposure. Self-reported occupational exposure was defined as regular (8 hours a week) and/or prolonged (at least 1 year) exposure to a predefined list of 14 industries (Aberle et al., 2010). First, participants were classified as positive for asbestos exposure if they reported employment with a documented asbestos-related industry. Two variables were constructed by summing exposures: 1) any exposures; and 2) silica exposure (e.g., coal, hard rock mining, sandblasting, foundry, steel mining).

Race was constructed by using two variables of race and ethnicity. These were 3 groups: non-Hispanic Whites, non-Hispanic African-Americans, and Others (e.g., Asian, Native Hawaiian or Pacific Islander, American Indian, Hispanic, or more than one race).

Control variables. Age, gender, smoking status, family history of lung cancer, body mass index (BMI), and pack-years of smoking were included as covariates. Age, BMI, and pack-years of smoking were used as continuous variables.

2.3.Statistical analysis

We used descriptive and analytic statistical methods in this study. First, we conducted bivariate analyses to examine the relations of race to variables including demographic, occupational exposures, and lung cancer development using cross-tabulation and ANOVA. Second, logistic regression was used to assess main effects and interaction effects. Interaction effects were tested by including a cross-product of smoking status and occupational exposures. Then, we conducted multivariate regression analysis while controlling for potential confounders such as age, gender, family history of lung cancer, BMI, smoking status, and pack-years of smoking. We used Stata version 14 for statistical analyses.

3. Results

3.1.Participant characteristics

The baseline characteristics of NLST participants have been previously described (Aberle et al., 2010). Of the total of 53,456 participants, 425 were unknown or declined to report race or ethnicity. Among those 53,027, 90% were non-Hispanic Whites, 4.4% were non-Hispanic African-Americans, and the remaining 5.6% were Others. Of the total cohort, 3.9% were diagnosed with lung cancer. African-Americans had the highest rate of lung cancer (4.3%) followed by Whites (3.9%) and Others (2.9%) (Table 1).

We found racial differences in background characteristics including age, gender, smoking status, pack-years, BMI, and family history of lung cancer. African-Americans (66.4%) were more likely to be current smokers than any other groups (47.2% for Whites and 48.7% for Others). In addition, African-Americans had lower mean pack-years than Whites (49 vs. 56).

3.2.Race, occupational exposures, and lung cancer incidence

Of the cohort of 53,001 participants, 28.1% reported ≥ 1 occupational exposures. African-Americans had a higher rate of occupational exposure than Whites (31.8% vs. 27.9%). African-Americans also had a higher rate of any silica exposures than Whites (9.9% vs. 6.3%). Participants of Others (7.1%) and African-Americans (6.9%) had higher rates of asbestos exposure than Whites (4.5%) (Table 1).

In a bivariate regression model, all three measures of occupational exposures and smoking status were associated with lung cancer diagnosis. As the interactions between exposures and smoking status were significantly associated with the outcome, these terms were included in the multivariate regression model.

In multivariate regression analyses, the interactions of all measures of occupational exposures and smoking status remained significant: current smokers with occupational exposures had higher odds of lung cancer diagnosis (aOR = 2.01, 95% CI = 1.76–2.30 for any exposure; aOR = 2.35, 95% CI = 1.89-2.91 for silica; aOR = 1.97, 95% CI = 1.52 -2.56 for asbestos), compared to former smokers without any exposures. Current smokers without exposures also had higher odds of lung cancer diagnosis (aOR =1.75 to 1.77) than former smokers without exposures. In addition, race was associated with lung cancer diagnosis: compared to Whites, African-Americans had higher risk of lung cancer diagnosis (aOR=1.24 to 1.25) and individuals of other races had lower risk of lung cancer diagnosis (aOR=0.76) (Table 2).

4. Discussion

This is one of the first studies to use a large dataset to examine the racial differences in occupational risk of lung cancer. We found that despite the small sample of African American participants included in the NLST, this group had significantly higher occupational exposure and higher odds of lung cancer diagnosis compared to White participants. African-Americans had higher odds of lung cancer even after controlling for potential confounders. Such findings are consistent with other data on racial disparities in cancer mortality in the US and are the result of a multitude of social, economic, behavioral and geographic factors linked to the social determinants of health that result in African-Americans being at greater risk (Chu et al., 2007; DeLancy et al., 2008). For example, researchers have identified that fatalistic beliefs and mistrust of the medical community among African-Americans may partially explain delayed lung cancer diagnoses and contribute to higher rates of late-stage diagnoses in this group (Bergamo et al., 2013). Moreover, current socioeconomic constructs result in African-Americans working jobs that involve higher occupational exposures, subsequently putting them at greater risk of not only lung cancer but all-cause mortality as well (Fujishiro et al., 2017).

Our study also noted that silica exposure was independently associated with lung cancer diagnosis, and that smoking modified the effect of occupational exposure on lung cancer diagnosis. Our data demonstrating significant interactions between occupational exposures (any exposure, silica and asbestos, respectively) are supported by the literature and suggest that these risk factors may have a multiplicative effect on lung cancer risk, underscoring the need for assessment of both occupational and smoking history by healthcare providers (Lee, 2001; Lai et al., 2018).

This analysis is limited by several factors. First, the NLST cohort was limited to subjects at high risk of lung cancer based on smoking history. The majority of NLST participants were White and had high education levels. Further, African-Americans represent 13% of the total US population but only 5% in the current sample, suggesting that the study has limited generalizability. Second, participants' self-reported occupational histories may be complicated by recall bias and lack of objective measures for exposure severity.

Our findings have multiple public policy implications. First, current lung cancer screening guideline recommend LDCT for high risk patients as defined by age and smoking intensity (Moyer, 2014). The guideline does not take into consideration race and smoking status, leading to underrepresetation of African-Americans in lung cancer screening cohorts (Aldrich et al., 2019). Second, African-Americans reported more frequent exposure than Whites to occupations which put them at risk for lung cancer. Due to social and economic reasons, African-Americans are more likely to have jobs with high occupational risks. Although many occupational exposures including silica and asbestos have been associated with lung cancer diagnosis, this evidence has yet to be translated into effective screening practices. We call for structural interventions, including partnerships between health systems and private industry, to educate workers about the importance of prevention, including lung cancer screening. Targeted outreach and education efforts at the community or workplace levels have the potential to protect African-Americans from increased lung cancer risk due to occupational exposures (Baron et al., 2009).

In order to advocate for interventions to address cancer-specific health disparities, researchers need access to better sources of data containing study samples that accurately reflect target population demographics. While enrollment in cancer clinical trials has increased over time, racial and ethnic minorities continue to be disproportionately underrepresented in clinical trials, and occupational exposure studies (Regnate et al., 2019; Stewart, 2001).

This study represents one of the first efforts to investigate the effect of racial disparities on occupational exposure and lung cancer diagnosis using a national dataset. We call for greater implementation of risk-based lung cancer screening practices and occupational protections for vulnerable patients and for effective prevention programs to reduce racial disparities in lung cancer. Future studies should investigate whether targeted lung cancer screening improves lung cancer detection for workers with exposure to silica, asbestos, and other lung carcinogens.

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Table 1. Background characteristics, occupational exposures, and lung cancer diagnosis in the National Lung Screening Trial (NLST)

	Total (n=53,027)		Non-Hispanic Whites (n=47,744)		Non-Hispanic African-Americans (n=2,341)		Other Races[a] (n=2,942)	
Demographic and clinical characterisitics								
Male Gender, n(%)	31,289	(59.0%)	28,059	(58.8%)	1,283	(54.8%)	1,947	(66.2%)
Age (mean ± SD)	61.4±5.02		61.5±5.03		60.5±4.78		61.3±5.06	
Smoking status, n(%)								
Former	27,505	(51.9%)	25,211	(52.8%)	786	(33.6%)	1,508	(51.3%)
Current	25,522	(48.1%)	22,533	(47.2%)	1,555	(66.4%)	1,434	(48.7%)
Smoking pack-years (mean ± SD)	55.9±23.9		56.3±24.0		49.0±19.0		55.0±25.2	
BMI (mean ± SD)	27.9±5.1		27.9±5.0		28.6±5.6		27.6±5.0	
Family history of lung cancer	10,985	(20.7%)	10,037	(21.0%)	444	(19.0%)	504	(17.0%)
Occupational exposures								
	N=53,001		N=47,772		N=2,337		N=2,942	
Any exposure (1+), range 0-12	28.1%		27.9%		31.8%		28.2%	
Silica (1+), range 0-4	6.5%		6.3%		9.9%		7.0%	
Asbestos	4.7%		4.5%		6.9%		7.1%	
Baking	2.2%		2.1%		4.1%		2.5%	
Butchering/meat packing	2.2%		2.2%		2.5%		2.5%	
Chemical/plastics manufacturing	6.2%		6.1%		9.5%		5.9%	
Coal mining	0.6%		0.7%		0.4%		0.4%	
Cotton/jute processing	0.7%		0.7%		2.4%		0.6%	
Farming	10.7%		11.0%		6.9%		8.9%	
Fire fighting	1.9%		1.9%		0.9%		1.9%	
Flour/feed or grain milling	1.1%		1.1%		0.7%		1.0%	
Foundry/steel milling	4.2%		4.1%		7.7%		3.7%	
Hard rock mining	0.8%		0.8%		0.5%		0.8%	
Painting	5.3%		5.0%		7.8%		7.5%	
Sandblasting	1.7%		1.6%		2.7%		3.1%	
Welding	5.6%		5.5%		6.3%		6.8%	
Lung cancer diagnoses								
Lung cancer diagnosis (n=53,027)	2,037	3.8%	1,850	3.9%	101	4.3%	86	2.9%
Lung cancer stage (n=2,037)								
Stage I	827	40.6%	746	40.3%	45	44.6%	36	41.9%
Stage II	145	7.1%	131	7.1%	5	5.0%	9	10.5%
Stage III	454	22.3%	409	22.1%	23	22.7%	22	25.6%
Stage IV	586	28.8%	542	29.3%	27	26.7%	17	19.7%
No stage recorded	25	1.2%	22	1.2%	1	1.0%	2	2.3%
Histology (n=2,013)								

-Adenocarcinoma	890	44.2%	819	44.8%	35	35.4%	36	42.9%
-Squamous cell carcinoma	461	22.9%	413	22.6%	24	24.2%	24	28.6%
-Large cell carcinoma	51	2.5%	42	2.3%	6	6.1%	3	3.6%
-Small cell carcinoma	282	14.0%	264	14.4%	10	10.1%	8	9.5%
-Carcinoid/ Neuroendocrine tumor	60	3.0%	59	3.2%	0	0%	1	1.2%
-Non-small cell carcinoma or other	269	13.4%	233	12.7%	24	24.2%	12	14.3%

Table 2: Relative odds of a lung cancer diagnosis according to race, smoking status, and occupational exposures (N=52,841)

	Lung cancer diagnosis [a] OR (95% CI)	**Lung cancer diagnosis [a] OR (95% CI)**	**Lung cancer diagnosis [a] OR (95% CI)**
Any exposure*smoking status		-	-
No exposure/former smoking	1.00		
No exposure/current smoking	1.77 (1.58-1.98)		
Any exposure/former smoking	1.17 (.99-1.36)		
Any exposure/current smoking	2.01 (1.76-2.30)		
Silica exposure*smoking status	-		-
No silica/former smoking		1.00	
No silica/current smoking		1.75 (1.59-1.94)	
Silica/former smoking		1.34 (1.03-1.74)	
Silica/current smoking		2.35 (1.89-2.91)	
Asbestos exposure*smoking status	-	-	
No asbestos/former smoking			1.00
No asbestos/current smoking			1.77 (1.60-1.95)
Asbestos/former smoking			1.30 (0.97-1.74)
Asbestos/current smoking			1.97 (1.52-2.56)
Race			
Non-Hispanic Whites	1.00	1.00	1.00
Non-Hispanic African-Americans	1.24 (1.01-1.53)	1.24 (1.01-1.52)	1.25 (1.01-1.54)
Others	0.76 (0.61-0.95)	0.76 (0.61-0.95)	0.76 (0.61-0.94)

[a]Adjusted for age, gender, family history of lung cancer, BMI, smoking status, and pack-years of smoking.