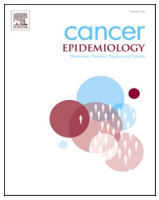
Cancer Epidemiology 79 (2022) 102194

Contents lists available at ScienceDirect

Cancer Epidemiology

journal homepage: www.elsevier.com/locate/canep



Association between lung cancer screening and smoking cessation

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ARTICLE INFO

Keywords:
Cigarettes
Smoking
Lung cancer
Screening

ABSTRACT

Introduction: Adults with high-risk smoking histories benefit from annual lung cancer screening. It is unclear if there is an association between lung cancer screening and smoking cessation among U.S. adults who receive screening.

Methods: We performed this population-based cross-sectional study using data from the Behavioral Risk Factor Surveillance System (2017–2020). We defined individuals eligible for lung cancer screening as adults 55–80 years old with ≥ 30 pack-year smoking history who were currently smoking or quit within the last 15 years. We assessed the association between lung cancer screening and current smoking status.

Results: Between 2017 and 2020, 12,382 participants met screening criteria. Current smoking was reported by 5685 (45.9 %) participants, of whom 40.4 % (2298) reported a cessation attempt in the prior year. Lung cancer screening was reported by only 2022 (16.3 %) eligible participants. Lung cancer screening was associated with lower likelihood of currently smoking (odds ratio [OR] 0.705, 95 % CI 0.626–0.793) compared to individuals who did not receive screening. Screening was also associated with higher likelihood of reporting a cessation attempt in the prior year (OR 1.562, 95 % CI 1.345–1.815) compared to individuals who did not receive screening.

Conclusions: Receipt of lung cancer screening was associated with lower smoking rates and more frequent cessation attempts among U.S. adults. Better implementation of lung cancer screening programs is critical and may profoundly increase smoking cessation in this population at risk of developing lung cancer.

1. Introduction

Lung cancer screening with low-dose computed tomography (LDCT) improves survival for individuals with high-risk smoking histories [1]. The United States Preventative Services Taskforce (USPSTF) recently expanded lung cancer screening eligibility to younger individuals with less extensive smoking histories [2]. In their updated recommendation, the USPSTF stressed the importance of smoking cessation among screening-eligible individuals due to its survival benefit [3]. While several trials have attempted to integrate smoking cessation into lung cancer screening programs, it remains unclear how successful these interventions have been on a population level [2,4]. Further, some fear that negative screening tests may reassure smokers to continue smoking [2]. In this study, we examined the association between lung cancer screening and smoking cessation practices among US adults.

2. Methods

We performed a cross-sectional cohort study using the Behavioral Risk Factor Surveillance System (BRFSS) between 2017 and 2020 [5]. The BRFSS, maintained by the Centers for Disease Control, conducts over 400,000 health-related telephone surveys annually of US residents regarding chronic health conditions, health risk behaviors, and utilization of preventative services. Since the dataset is publicly available and de-identified, the study was deemed Institutional Review Board exempt.

Screening eligibility was defined using 2013 USPSTF criteria as individuals 55–80 years old, with ≥ 30 pack-year smoking history, and currently smoking or quitting within the last 15 years, as previously described [6,7]. Our primary exposure of interest was receipt of LDCT screening (i.e., participants were asked "in the last 12 months, did you have a CT or CAT scan [to check for lung cancer]?"). We used multivariable logistic regression to assess the association between LDCT and

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https://doi.org/10.1016/j.canep.2022.102194
Received 28 February 2022; Received in revised form 27 May 2022; Accepted 1 June 2022
Available online 7 June 2022

Table 1
Characteristics of cigarette use and cessation attempts among U.S. adults eligible for lung cancer screening in the Behavioral Risk Factor Surveillance System, 2017–2020.

Variable	Total (n = 12,382)	Smoking status			Cessation attempt in last 12 months[a]		
		Former (n = 6697)	Current (n = 5685)	P-value	Attempt (n = 2298)	No attempt (n = 3387)	P-value
Age, mean (SD)	66.1 (6.9)	67.2 (7.1)	64.7 (6.5)	< 0.001	64.5 (6.4)	65.0 (6.6)	0.005
Sex (%)				0.50			< 0.001
Male	6794 (54.87)	3693 (55.14)	3101 (54.55)		1206 (52.48)	1895 (55.95)	
Female	5588 (45.13)	3004 (44.86)	2584 (45.45)		1092 (47.52)	1492 (44.05)	
Race (%)				0.01			0.001
White	11,117 (89.78)	6037 (90.14)	5080 (89.36)		2016 (87.73)	3064 (90.46)	
Black	416 (3.36)	239 (3.57)	177 (3.11)		92 (4.00)	85 (2.51)	
Other	849 (6.86)	421 (6.29)	428 (7.53)		190 (8.27)	238 (7.03)	
Body Mass Index (BMI, %)				< 0.001			< 0.001
Underweight (BMI < 18.5)	315 (2.54)	128 (1.91)	187 (3.29)		90 (3.92)	97 (2.86)	
Normal (BMI 18.5–25.0)	3583 (28.94)	1578 (23.56)	2005 (35.27)		743 (32.33)	1262 (37.26)	
Overweight (BMI 25.0–30.0)	4345 (35.09)	2435 (36.36)	1910 (33.6)		786 (34.2)	1124 (33.19)	
Obese (BMI > 30.0)	4139 (33.43)	2556 (38.17)	1583 (27.85)		679 (29.55)	904 (26.69)	
Marital Status (%)				< 0.001			0.13
Married	5361 (43.3)	3230 (48.23)	2131 (37.48)		835 (36.34)	1296 (38.26)	
Divorced	3298 (26.64)	1574 (23.5)	1724 (30.33)		737 (32.07)	987 (29.14)	
Never married	874 (7.06)	420 (6.27)	454 (7.99)		181 (7.88)	273 (8.06)	
Other	2849 (23.01)	1473 (21.99)	1376 (24.2)		545 (23.72)	831 (24.53)	
Education (%)[b]				< 0.001			0.36
Did not graduate high school	1345 (10.86)	593 (8.85)	752 (13.23)		323 (14.06)	429 (12.67)	
Graduated high school	4796 (38.73)	2487 (37.14)	2309 (40.62)		923 (40.17)	1386 (40.92)	
Attended college or technical school	3930 (31.74)	2142 (31.98)	1788 (31.45)		728 (31.68)	1060 (31.3)	
Graduated college of technical school	2311 (18.66)	1475 (22.02)	836 (14.71)		324 (14.1)	512 (15.12)	
Income (%)[c]				< 0.001			< 0.001
Less than $15,000	1649 (13.32)	709 (10.59)	940 (16.53)		451 (19.63)	489 (14.44)	
$15,000 to less than $25,000	2462 (19.88)	1198 (17.89)	1264 (22.23)		557 (24.24)	707 (20.87)	
$25,000 to less than $35,000	1437 (11.61)	748 (11.17)	689 (12.12)		260 (11.31)	429 (12.67)	
$35,000 to less than $50,000	1691 (13.66)	970 (14.48)	721 (12.68)		279 (12.14)	442 (13.05)	
$50,000 or more	3349 (27.05)	2077 (31.01)	1272 (22.37)		472 (20.54)	800 (23.62)	
Unsure/Other	1794 (14.49)	995 (14.86)	799 (14.05)		279 (12.14)	520 (15.35)	
Insurance (%)[d]				< 0.001			0.11
Yes	11,615 (93.81)	6450 (96.31)	5165 (90.85)		2105 (91.6)	3060 (90.35)	
No	767 (6.19)	247 (3.69)	520 (9.15)		193 (8.4)	327 (9.65)	
Primary healthcare provider (%)[e]				< 0.001			< 0.001
Yes	10,952 (88.45)	6190 (92.43)	4762 (83.76)		1985 (86.38)	2777 (81.99)	
No	1430 (11.55)	507 (7.57)	923 (16.24)		313 (13.62)	610 (18.01)	
Smoking Information							
PPD, mean (SD)	1.2 (0.7)	1.3 (0.8)	1.1 (0.7)	< 0.001	1.1 (0.9)	1.1 (0.5)	0.40
Years-smoked, mean (SD)	45.6 (8.1)	43.6 (8.1)	48.0 (7.5)	< 0.001	47.3 (7.5)	48.4 (7.5)	< 0.001
LDCT in last 12 months				0.001			< 0.001
Yes	2022 (16.33)	1161 (17.34)	861 (15.15)		425 (18.49)	436 (12.87)	
No	10,360 (83.67)	5536 (82.66)	4824 (84.85)		1873 (81.51)	2951 (87.13)	
Year				< 0.001			0.04
2017–2018	5502 (44.44)	3083 (46.04)	2419 (42.55)		1016 (44.21)	1403 (41.42)	
2019–2020	6880 (55.56)	3614 (53.96)	3266 (57.45)		1282 (55.79)	1984 (58.58)	

BMI = body mass index, PPD = packs per day.
[a] Of those respondents who were currently smoking.
[b] Assessed by asking "What is the highest grade or year of school you completed?".
[c] Assessed by asking "[What] is your annual household income from all sources?".
[d] Assessed by asking "Do you have any kind of health care coverage, including health insurance, prepaid plans such as HMOs, or government plans such as Medicare, or Indian Health Service?".
[e] Assessed by asking "Do you have one person you think of as your personal doctor or health care provider?"

outcomes including (1) smoking status (i.e., "do you now smoke cigarettes every day, some days, or not at all?") and (2) cessation attempts in the prior year among individuals currently smoking (i.e., "during the past 12 months, have you stopped smoking for one day or longer because you were trying to quit smoking?"). In separate models, we performed stratified analyses to better understand the association between LDCT and smoking cessation in younger individuals and individuals with less extensive smoking histories (since such individuals are now eligible for LDCT in updated USPSTF guidelines) [2]. Missing data were handled via complete case analyses (n = 12,382 participants, 8.5 % with missing data). Analyses with multiple imputation of missing data are available in the supplement (n = 13,525 participants). Descriptive statistics and standard errors were estimated using survey population weights [5]. Statistical analyses were performed using SAS Studio 3.81 (SAS Institute, Cary, NC).

3. Results

Between 2017 and 2020, 12,382 participants met screening eligibility of whom 5685 (45.9 %) were currently smoking. Current smoking was associated with younger age, lower BMI, single marital status, less education, lower income, and lack of health insurance or a primary care provider (Table 1). Among individuals currently smoking, at least 1 cessation attempt in the prior year was reported by 40.4 % (2298). Cessation attempt was associated with younger age, female sex, non-white race, lower income, and having a primary care provider (Table 1).

LDCT screening was reported by 2022 (16.3 %) eligible participants. Receipt of LDCT was associated with lower likelihood of currently

Table 2
Association of LDCT screening with smoking status and cessation practices stratified by age and smoking history, adjusted results.

		Stratified by age		Stratified by smoking history	
	All respondents[a]	< 65 years old[a,b]	≥ 65 years old[a,b]	< 50 pack-years[a]	≥ 50 pack-years[a]
Total no. of respondents	12,382	5639	6743	6999	5383
Currently smoking, odds ratio (95 % CI)[c]	0.705 (0.626–0.793)	0.616 (0.512–0.741)	0.758 (0.649–0.884)	0.701 (0.593–0.828)	0.710 (0.600–0.841)
Cessation attempt in last year, odds ratio (95 % CI)[cd]	1.562 (1.345–1.815)	1.605 (1.282–2.009)	1.530 (1.247–1.876)	1.525 (1.239–1.876)	1.619 (1.300–2.015)

[a] Estimate for receiving LDCT (yes vs. no).
[b] Arbitrary age cutoff to allow roughly equal sample sizes in both groups.
[c] Multivariable logistic regression models adjusting for age, sex, race, BMI, marital status, education level, income, insurance status, primary care physician status, survey year, smoking dose (packs per day smoked), and smoking duration (years).
[d] Of those respondents who were currently smoking

smoking (odds ratio [OR] 0.705, 95 % CI 0.626–0.793) compared to individuals who did not receive LDCT. LDCT was also associated with higher likelihood of reporting a cessation attempt in the prior year (OR 1.562, 95 % CI 1.345–1.815). The associations between LDCT screening and smoking status and cessation attempts were similar across different age groups (< 65 vs. ≥ 65 years old) and smoking histories (< 50 vs. ≥ 50 pack-years, Table 2). Of note, results did not differ substantially in the imputed analyses.

4. Discussion

In this population-based cohort of US adults eligible for lung cancer screening, receipt of LDCT was associated with lower smoking rates and more frequent cessation attempts. Some providers have expressed concerns that lung cancer screening may inadvertently reassure smokers to continue smoking, even though several studies have contradicted this idea [2]. Our population-based data further negate this fear by showing that smoking rates are in fact lower among screened US adults. It is also notable, since USPSTF guidelines now include younger individuals with less extensive smoking histories [7], that the association between LDCT and smoking cessation was comparable across different age groups and smoking histories. Together, these data indicate that the integration of smoking cessation and screening programs may be decreasing smoking rates successfully in this highly vulnerable population of adults. These findings are particularly encouraging given the well-established association between persistent smoking and worse lung cancer outcomes [8,9].

Few studies have examined the association between lung cancer screening and smoking cessation, particularly at a population level. The USPSTF in their 2021 updated guidelines identified only 7 studies (mostly randomized controlled trials or cohort studies) that evaluated the impact of lung cancer screening or screening results on smoking cessation or relapse [10]. In general, these studies found that lung cancer screening programs can improve smoking abstinence, though the direct effect of lung cancer screening on smoking behavior may be minimal and rather reflect contextual advantages of frequent healthcare encounters [11]. Our study adds to this literature by showing that these findings apply not just to these highly selected trial populations but also to the general U.S. population. Additionally, our subgroup analyses demonstrate that these findings do not differ based on age or severity of smoking history. Therefore, our findings directly address gaps in knowledge that were identified by the USPSTF [10].

Perhaps the most notable finding of this study is the dramatic underutilization of lung cancer screening in the United States, with only 16 % of eligible adults being screened. Given the expanded population of individuals now eligible for screening, it will be important to monitor screening rates to ensure that this improves [2]. Additionally, improving adherence to follow-up screening tests will be critical for maximizing cancer prevention and augmenting outcomes in screening-eligible patients [12,13].

This study has several limitations. The BRFSS is a population-based, cross-sectional survey which carries risk of bias inherent to the sampling design. Additionally, lung cancer screening results are unavailable in the data. Finally, the temporal relationship between LDCT screening and smoking cessation is difficult to assess in these non-longitudinal survey data.

In conclusion, in this population-based study of adults eligible for lung cancer screening, appropriate screening was associated with lower smoking rates and more frequent cessation attempts. Better implementation of lung cancer screening programs may profoundly increase smoking cessation in this high-risk population of US adults.

Meeting Presentations

None.

Author Contribution Statement

All authors made substantial contributions to 1) the conception and design, acquisition of data, or analysis and interpretation of data; 2) the drafting of the article or revising it critically for important intellectual content; and 3) the final approval of the version to be published.

CRediT authorship contribution statement

Brendan T. Heiden, MD, MPHS: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Kathryn E. Engelhardt, MD, MS:** Conceptualization, Writing – review & editing. **Chao Cao, MPH:** Conceptualization, Methodology, Writing – review & editing. **Bryan F. Meyers, MD, MPH:** Conceptualization, Writing – review & editing. **Varun Puri, MD, MSCI:** Conceptualization, Writing – review & editing. **Yin Cao, MPH, ScD:** Conceptualization, Methodology, Writing – review & editing. **Benjamin D. Kozower, MD, MPH:** Conceptualization, Writing – review & editing.

Funding

Funded in part by National Insititutes of Health (NIH), United States 5T32HL007776-25 (BTH).

Conflicts of Interest

The authors have no conflicts of interest.

Acknowledgements

None.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.canep.2022.102194.

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