Original investigation

Longitudinal Associations of Cigarette Prices With Smoking Cessation: The Coronary Artery Risk Development in Young Adults Study

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Abstract

Introduction: Few studies have used longitudinal cohort data to examine associations of cigarette prices with smoking cessation or whether price sensitivity varies by income or education. This study examines these associations in a multicenter US cohort and explores whether associations vary by education and income.

Methods: Longitudinal data from baseline daily cigarette smokers aged 18–30 years in the Coronary Artery Risk Development in Young Adults study were linked to inflation-adjusted cigarette carton prices from the Council for Community and Economic Research Cost of Living Index based on residential address at baseline and in years 7, 10, and 15 (1985–2001). Multivariable Cox models estimated hazard ratios (HRs) of first (any) smoking cessation and sustained smoking cessation (no relapse) associated with each $1 increase in time-dependent cigarette price over 15 years of follow-up. Models were adjusted for sociodemographic, health-related, and policy covariates. We assessed effect modification by education and household income.

Results: Among 1489 participants, a $1.00 higher cigarette carton price was associated with a 16% higher likelihood of first smoking cessation (HR = 1.16, 95% CI = 1.11 to 1.21) and an 8% higher likelihood of sustained smoking cessation (HR = 1.08, 95% CI = 1.02 to 1.14). Associations were strongest among participants with lower income for first cessation, and among those with higher income for sustained cessation. Associations were strongest for participants with less than a high school degree for both outcomes.

Conclusions: Results suggest higher cigarette prices promote smoking cessation among young to middle-aged adults, and that price sensitivity may differ by socioeconomic status.

Implications: Few studies have examined longitudinal associations of cigarette prices with smoking cessation, and findings are mixed on whether price sensitivity varies by education or income. In a cohort of US adult daily smokers, cigarette prices were associated with greater likelihood of both a first cessation and sustained cessation. Price associations with first cessation were stronger among low-income smokers, but associations with sustained cessation were stronger among

high-income smokers. Results suggest that although higher cigarette prices may promote short-term smoking cessation among smokers at all income levels, additional supports may be needed to facilitate sustained smoking cessation among low-income smokers.

Introduction

Cigarette smoking remains one of the largest causes of preventable death in the United States, resulting in nearly 500 000 deaths per year.[1] Tax increases have been levied at the federal, state, and local level in the United States as a tobacco control measure. Previous studies have estimated price elasticities of –0.1 to –0.6 for smoking prevalence and intensity, indicating that a 10% increase in price would reduce per capita tobacco consumption between 1% and 6% among adults.[2–6]

Most prior studies of cigarette prices or taxes and smoking behavior have used repeat cross-sectional surveys to examine associations with smoking prevalence and intensity.[4–16] Although this approach allows examination of population-level changes, longitudinal cohort studies are particularly well suited to examine associations of cigarette prices with individual-level smoking behavior changes over time. However, relatively few prior studies have used longitudinal cohort data to examine associations of cigarette prices with smoking cessation.[17–21] Studies that have examined cessation have generally used state-level cigarette prices.[17–19,21] As cigarette prices may vary substantially within states,[22–24] examining associations of price at smaller geographic scales may better reflect prices to which individuals are exposed.

Smoking prevalence is highest among people with lower levels of education and income.[25] Lower income smokers may be particularly responsive to cigarette price increases, as price increases make up a larger share of their available income. However, prior results are mixed with regard to whether individuals with lower income or education are more sensitive to changes in cigarette prices.[6–9,12,14,19,20,26] Reflecting overall patterns, most analyses examining differences by income or education have used repeat cross-sectional data and have focused on disparities in smoking prevalence and cigarette consumption, rather than individual-level cessation.[6–9,12,14]

Our objective was to estimate associations of cigarette prices with smoking cessation among young to middle-aged US adults over a 15-year period, and to determine whether associations varied by household income and educational attainment. We hypothesized that higher prices would be associated with greater likelihood of cessation and that associations would be stronger among participants with lower income and educational attainment.

Methods

Study Sample

The Coronary Artery Risk Development in Young Adults (CARDIA) study is a multicenter, longitudinal cohort study that enrolled 5115 black and white men and women aged 18–30 from four cities (Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California) in 1985–1986. A stratified recruitment methodology was used to obtain balance by age, gender, race, and education.[27] Participants were followed for 30 years, with follow-up exams conducted after 2, 5, 7, 10, 15, 20, 25, and 30 years. Retention rates were 91%, 86%, 81%, 79%, 74%, 72%, 72%, and 71%, respectively. The institutional review board at each participating institution approved the CARDIA study and all participants provided written informed consent.

Data for these analyses included examination years 0–15 (1985–2001) based on the timing of the cigarette pricing data that was linked to CARDIA participants. Our analytic sample included participants who reported smoking at least one cigarette per day at the baseline examination ($n = 1546$). We excluded participants who reported being pregnant at the time of any examination ($n = 57$) to avoid including cessation events that were due to pregnancy, for a final sample size of 1489 participants.

Cigarette Prices

Cigarette price data were from the Council for Community and Economic Research (C2ER) Cost of Living Index.[28] C2ER ascertained prices on a quarterly basis for more than 60 consumer goods and services to estimate cost of living in approximately 300 US cities. C2ER ascertained the price of a carton of Winston, king-size cigarettes from each location. Prices were adjusted for inflation to US $2000 using the Bureau of Labor Statistics' Consumer Price Index[29] to estimate associations for a consistent dollar amount over the course of 15 years of follow-up. Residential addresses of CARDIA participants were geocoded at baseline and in years 7, 10, and 15. Cigarette prices from C2ER were linked to participants in these years based on their examination date (quarter and year) and their geocoded residence. Prices were assigned based on the smallest geographic unit for which a match was available: county-level (49%), core-based statistical area (30%), and population-weighted state-level (21%). We estimated associations for a $1 higher cigarette carton price. As cartons typically contain 10 packs of cigarettes, this reflects an approximate increase of $0.10 per pack. However, as cartons may provide a discount relative to purchasing 10 separate packs,[30] results may not be directly translatable to a per-pack increase.

Outcomes

Cigarette smoking status and the average number of cigarettes smoked per day were assessed at each examination by self-report in response to an interviewer-administered questionnaire using the following questions: (1) "Have you ever smoked cigarettes regularly for at least 3 months? By regularly, we meant at least 5 cigarettes per week, almost every week." (2) "Do you still smoke cigarettes regularly?" (3) "How many cigarettes do you smoke per day on average?" In addition, participants were contacted by yearly telephone follow-up between examinations and asked to report the average number of cigarettes smoked per day. Participants who reported smoking at least one cigarette per day were considered current smokers, and participants reporting not smoking at least one cigarette per day were considered nonsmokers. Daily smoking was used to define smoking status consistently between the examinations and the annual phone follow-up contacts.

As a prior study found relapse after smoking cessation to be common among CARDIA participants,[31] we examined two outcomes: (1) first cessation and (2) sustained cessation. First cessation was

defined as reporting smoking zero cigarettes per day at a follow-up examination or annual telephone follow-up for the first time. The date that participants first reported smoking zero cigarettes per day was considered the date of first cessation. Sustained cessation was defined as reporting smoking zero cigarettes per day at an examination or telephone follow-up and also at all subsequent examinations and follow-ups, with no relapse. The date when participants who reported smoking zero cigarettes per day at all subsequent follow-ups first reported smoking zero cigarettes per day was considered the date of sustained cessation. Smokers whose first cessation was reported at the examination year 15 (last follow-up during the study period) were not counted as having sustained cessation.

Covariates

Covariates included individual-level sociodemographic, behavioral, clinical, and policy characteristics a priori identified as potentially associated with smoking cessation and cigarette prices. Sociodemographic covariates were assessed using standardized questionnaires. Participants reported their age, gender, and race at baseline. At all examinations, participants reported educational attainment (years), marital status (married/living in a marriage-like relationship vs. not), and alcohol use (use in the past year vs. not). Physical activity was assessed in average self-reported exercise units by validated questionnaire.[32] Total family income was collected starting in year 5 as a nine-level ordinal variable and was converted to a continuous variable using the average dollar value for each category. Incomes were adjusted for inflation using the Consumer Price Index.[29] In the clinic, participant weight (kg) and height (cm) were measured at each visit and body mass index was calculated in kg/m².

We also controlled for whether participants had a chronic health condition that might influence smoking cessation, including hypertension, diabetes, asthma, cancer, and cardiovascular disease. At each examination, seated resting systolic and diastolic blood pressures were measured three times using a random zero mercury sphygmomanometer and the second and third measurements were averaged. Hypertension was defined as systolic blood pressure at least 140 mm Hg, diastolic blood pressure at least 90 mm Hg, or self-reported hypertension medication use. Diabetes was defined as fasting glucose at least 126 mg/dL, 2-hour glucose tolerance test at least 200 mg/dL, or self-reported use of medication for the treatment of diabetes. Current asthma was defined based on self-report and use of asthma medications. Other health conditions, including cancer and heart disease, were assessed via self-report at each examination.[33]

Starting in year 5, participants who were employed indoors were asked to report whether or not there was a prohibition on smoking in their workplace. We compared those with a total ban to all others. We also linked state, county, and local laws that prohibited smoking in all restaurants, bars, or workplaces to participants in years 0, 7, 10, and 15 based on their geocoded residential address and examination date. Smoke-free policy data came from the American Nonsmokers' Rights Foundation's local ordinance database.[34]

Statistical Analysis

We used Cox proportional hazard models to estimate adjusted hazard ratios of (1) first smoking cessation and (2) sustained smoking cessation associated with a $1 increase in cigarette carton price. Follow-up time was calculated from the baseline examination until the date of smoking cessation or censoring. Participants were censored at their last contact date if no cessation occurred. We modeled cigarette price as a time-dependent variable, which was updated in years 7, 10, and 15. Models were progressively adjusted. Model 1 was unadjusted. Model 2 adjusted for sociodemographic characteristics (baseline age, gender, race, field center, educational attainment, time-dependent marital status, and inflation-adjusted household income). Model 3 additionally adjusted for time-dependent health behaviors (alcohol use and physical activity). Model 4 additionally adjusted for time-dependent body mass index and presence of a chronic health condition. Model 5 additionally adjusted for time-dependent policy covariates: self-report of a complete workplace smoking prohibition and whether participants lived in an area with a smoke-free law covering all bars, restaurants, and workplaces. Multiple imputation by chained equations[35] was used to impute missing covariate values by creating 10 imputed datasets.

To test for effect modification, we repeated the fully adjusted models and added cross-product interaction terms between time-dependent cigarette price and continuous (1) household income, (2) educational attainment, (3) baseline smoking intensity; and (4) dichotomous presence of a chronic health condition. Subgroup-specific adjusted hazard ratios were calculated. Educational attainment was categorized as follows: less than 12 years (less than a high school degree), 12 years (corresponding with high school graduation), 13–15 years (some college/associate's degree), and at least 16 years (corresponding with attaining a bachelor's degree). Average household income across follow-up was categorized into tertiles. Baseline smoking intensity was categorized as less than or equal to 10 cigarettes per day (half a pack) versus more than 10 cigarettes per day. Participants who ever had a chronic health condition during follow-up were compared to those who never did. All analyses were conducted using SAS, version 9.4 (SAS Institute, Inc, Cary, NC).

Results

Among 1489 baseline daily smokers, 875 (58.8%) reported smoking zero cigarettes at a follow-up examination or annual telephone call (first cessation). In addition, 432 (29.0%) reported sustained smoking cessation (cessation with no relapse by the end of follow-up). Characteristics positively associated with first cessation in bivariate analyses included older baseline age, female gender, white race, higher educational attainment, higher income, higher body mass index, higher physical activity, and reporting a policy prohibiting smoking in their workplace (Table 1). Patterns were similar for sustained cessation, although there was no difference in body mass index, and those with a sustained cessation had lower baseline physical activity (Table 1). Few participants lived in areas with smoke-free policies (4.0% lived in areas with smoke-free policies in bars and restaurants, and 4.1% in areas with smoke-free policies in other workplaces).

Table 2 presents the percentage of participants with a first cessation and sustained cessation among education and income subgroups. As education and income increased, the percentage with both a first and sustained cessation increased (Table 2; *p* for trend <.001). Inflation-adjusted cigarette carton prices (in 2000 US dollars) increased over time, from an average of $14.59 at baseline (1985–1986) to $30.86 in year 15 (2000–2001). Variability in cigarette prices increased over time, from a range of $13.18–$15.67 in year 0 to a range of $22.26–$40.95 in year 15.

Associations of Price With First Smoking Cessation

In unadjusted models, a $1 higher cigarette carton price was associated with a 13% increase in the likelihood of first smoking

Table 1. Description of Baseline Characteristics[a] of the Study Population, Overall and by Smoking Cessation Status, the Coronary Artery Risk Development in Young Adults (CARDIA) Study, 1985–2001, *N* = 1489 Baseline Daily Smokers

	Overall	Quit smoking (first cessation)[b]	No first cessation	*p* value[c]	Quit smoking (sustained cessation)[b]	No sustained cessation	*p* value[c]
N	1489	875	614		432	1057	
Baseline age, mean (SD), years	25.0 (3.6)	25.2 (3.5)	24.8 (3.8)	<.0001	25.1 (3.5)	25.0 (3.7)	.05
Gender, N (%)				.01			.02
Male	730 (49.0)	405 (46.3)	325 (52.9)		192 (44.4)	538 (50.9)	
Female	759 (51.0)	470 (53.7)	289 (47.1)		240 (55.6)	519 (49.1)	
Race, N (%)				<.0001			<.0001
Black	862 (57.9)	467 (53.4)	395 (64.3)		206 (47.7)	656 (62.1)	
White	627 (42.1)	408 (46.6)	219 (35.7)		226 (52.3)	401 (37.9)	
Maximum education, mean (SD) years[d]	13.8 (2.3)	14.3 (2.4)	13.0 (2.0)	<.0001	14.5 (2.5)	13.5 (2.2)	<.0001
Household income, mean (SD), per $10 000[e]	4.3 (2.8)	4.7 (2.9)	3.6 (2.4)	<.0001	5.2 (2.9)	3.9 (2.7)	<.0001
Married/living as married, N (%)	287 (19.3)	172 (19.7)	115 (18.7)	.7	82 (19.0)	205 (19.4)	.9
Alcohol use in past year, N (%)	1394 (93.6)	814 (93.0)	580 (94.5)	.3	409 (94.7)	985 (93.2)	.3
Total physical activity, mean (SD)[f]	404.9 (293.2)	412.1 (301.0)	394.7 (281.4)	.0003	397.2 (272.3)	408.1 (301.3)	.03
Body mass index, mean (SD), kg/m²	24.5 (5.1)	24.6 (5.0)	24.3 (5.2)	.0004	24.4 (4.6)	24.5 (5.3)	.2
Smoking-related health condition at baseline, N (%)[g]	312 (21.0)	189 (21.6)	123 (20.0)	.5	94 (21.8)	218 (20.6)	.6
Workplace smoking ban (self-reported) N (%)[h]	212 (14.2)	156 (17.8)	56 (9.1)	<.0001	79 (18.3)	133 (12.6)	.004

[a]Characteristics presented are from the initial examination (1985–1986) unless otherwise noted.

[b]Outcomes included first cessation and sustained cessation. "Quit smoking (first cessation)" indicates a participant who was a current smoker at baseline and reported being a nonsmoker/smoking zero cigarettes per day at a follow-up examination or annual telephone contact, regardless of whether or not they later relapsed. "Quit smoking (sustained cessation)" indicates a participant who reported a first cessation and then reported being a nonsmoker/smoking zero cigarettes per day at all subsequent follow-up examinations or annual telephone contacts (cessation with no relapse).

[c]*p* values are from chi-squared tests for categorical variables and *t* tests for continuous variables.

[d]Education was reported in every year. These values reflect maximum educational attainment over the follow-up period.

[e]Income was first reported in year 5. These values reflect the average income over follow-up (years 5–15), adjusted for inflation to 2000 US dollars.

[f]Physical activity was measured in self-reported exercise units that accounted for the frequency and intensity of each activity.

[g]Including asthma, hypertension, cancer, heart disease, or diabetes. This variable was constructed to adjust for health conditions that might influence participants to quit smoking.

[h]In year 5. Self-reported workplace smoking policy was not recorded in year 0.

Table 2. Percentage of Participants Quitting Smoking (First and Sustained Cessation), by Socioeconomic Status Subgroups, the Coronary Artery Risk Development in Young Adults (CARDIA) Study, 1985–2001, *N* = 1489 Baseline Daily Smokers

	N	First smoking cessation[a] N (row %)	*p* for trend[b]	Sustained smoking cessation[a] N (row %)	*p* for trend[b]
Education category[c]			<0.0001		<0.0001
<12 y	142	52 (36.6)		21 (14.8)	
12 y (high school degree)	442	215 (48.6)		103 (23.3)	
13–15 y	559	339 (60.6)		155 (27.7)	
≥16 y	346	269 (77.7)		153 (44.2)	
Income tertile[d]			<0.0001		<0.0001
Tertile 1 (lowest)	509	233 (45.8)		95 (18.7)	
Tertile 2	495	291 (58.8)		129 (26.1)	
Tertile 3 (highest)	485	351 (72.4)		208 (42.9)	

[a]Outcomes included first cessation and sustained cessation. "Quit smoking (first cessation)" indicates a participant who was a current smoker at baseline and reported being a nonsmoker/smoking zero cigarettes per day at a follow-up examination or annual telephone contact, regardless of whether or not they later relapsed. "Quit smoking (sustained cessation)" indicates a participant who reported a first cessation and then reported being a nonsmoker/smoking zero cigarettes per day at all subsequent follow-up exams or annual telephone contacts (cessation with no relapse).

[b]*p* values are from logistic regression of the smoking cessation outcomes on ordinal education and income.

[c]Education was reported in every year. These values reflect maximum educational attainment over the follow-up period.

[d]Income was first reported in year 5. These values reflect the average income over follow-up (years 5–15), adjusted for inflation to 2000 US dollars. Income tertiles were as follows: tertile 1 = ≤$25 545; tertile 2 = $25 543–$48 539; tertile 3 = ≥$48 540.

cessation (adjusted hazard ratio = 1.13, 95% confidence interval [CI] = 1.08 to 1.17; Table 3). Results changed little on covariate adjustment. In subgroup analyses, cigarette prices were significantly associated with first cessation in all subgroups (Table 3).

Associations were strongest among participants in the lowest tertile of household income (HR = 1.23, 95% CI = 1.12 to 1.34 compared to HR = 1.14, 95% CI = 1.05 to 1.24 and HR = 1.12, 95% CI = 1.04 to 1.20 in the middle and highest tertile). There

Table 3. Associations of a $1 Higher Inflation-Adjusted Cigarette Carton Price (in 2000 US Dollars) With First Smoking Cessation,[a] the Coronary Artery Risk Development in Young Adults (CARDIA) Study, 1985–2001, *N* = 1489 Baseline Daily Smokers

	N	Adjusted hazard ratio (95% CI)	*p* interaction[b]
Pooled association[c]			
Model 1: unadjusted	1489	1.13 (1.08 to 1.17)	—
Model 2: adjusted for sociodemographics	1489	1.16 (1.11 to 1.21)	—
Model 3: Model 1 + health behaviors	1489	1.16 (1.12 to 1.21)	—
Model 4: Model 2 + clinical covariates	1489	1.16 (1.12 to 1.21)	—
Model 5: Model 3 + policy covariates	1489	1.16 (1.11 to 1.21)	—
By subgroup (Model 5)[d]			
Average household income[e]			.04
Income tertile 1 (lowest)	505	1.23 (1.12 to 1.34)	
Income tertile 2	501	1.14 (1.05 to 1.24)	
Income tertile 3 (highest)	483	1.12 (1.04 to 1.20)	
Maximum educational attainment			.3
<12 y	142	1.32 (1.10 to 1.58)	
12 y	442	1.13 (1.04 to 1.22)	
13–15 y	559	1.15 (1.07 to 1.23)	
≥16 y	346	1.15 (1.05 to 1.25)	
Baseline smoking intensity			.02
≤10 cigarettes per day	790	1.12 (1.05 to 1.19)	
>10 cigarettes per day	699	1.21 (1.14 to 1.28)	
Presence of a chronic health condition[f]			.9
Yes	962	1.14 (1.08 to 1.21)	
No	527	1.18 (1.09 to 1.27)	

[a]"First smoking cessation" was defined as the first examination or yearly telephone follow-up at which the participant reported smoking zero cigarettes per day.
[b]*p* values are from interaction product terms between price and (1) continuous income, (2) continuous education, (3) continuous smoking intensity, and (4) dichotomous presence of a chronic health condition.
[c]Results are from multivariable extended Cox models and reflect hazard ratios for first smoking cessation associated with a $1 higher cigarette carton price. Model 1 is unadjusted. Model 2 adjusted for baseline age, gender, race, field center, maximum educational attainment, and time-dependent marital status and inflation-adjusted household income. Model 3 additionally adjusted for current alcohol use and physical activity. Model 4 additionally adjusted for body mass index and presence of a self-reported chronic health condition (asthma, hypertension, diabetes, cancer, heart disease). Model 5 additionally adjusted for self-report of a full prohibition on smoking in the workplace, and living in an area with laws banning smoking in all restaurants, bars, and other workplaces.
[d]Subgroup analyses are adjusted for all covariates except the variable used to define the subgroup.
[e]Income tertiles were as follows: tertile 1 = ≤$25 545; tertile 2 = $25 543–$48 539; tertile 3 = ≥$48 540.
[f]Chronic health conditions included hypertension, diabetes, asthma, cancer, and cardiovascular disease. We compared those who ever had a chronic health condition during the follow-up period to those who did not.

was evidence of a continuous interaction of price with income (*p* interaction: .04). Cigarette price was most strongly associated with first cessation among participants with less than 12 years of educational attainment (HR = 1.32, 95% CI = 1.10 to 1.58; Table 3), although the interaction term for price and continuous education was not statistically significant (*p* interaction: .3). Cigarette price was more strongly associated with first cessation among participants who smoked more than 10 cigarettes per day at baseline (*p* interaction: 0.02); however, there was no difference comparing those with and without a chronic health condition (*p* interaction: .9).

Associations of Price With Sustained Smoking Cessation

Overall, a $1 higher cigarette carton price was associated with an 8% increase in the likelihood of sustained smoking cessation (HR = 1.08, 95% CI = 1.02 to 1.14 in the fully adjusted model; Table 4). Patterns for educational attainment were similar to those for first cessation, with the strongest association among participants with less than 12 years of educational attainment (HR = 1.39, 95% CI = 1.00 to 1.93, *p* interaction: .8). However, for income, patterns differed. Cigarette prices were most strongly associated with sustained cessation among participants in the highest income tertile (HR = 1.15, 95% CI = 1.06 to 1.25), although there was no

evidence of an interaction with continuous income (*p* interaction: .3). Cigarette prices were associated with sustained cessation among participants who smoked more than 10 cigarettes per day at baseline (HR = 1.18, 95% CI = 1.08 to 1.29) and among those who did not have a chronic health condition (HR = 1.14, 95% CI = 1.04 to 1.25).

Discussion

Among 1489 young to middle-aged adult daily smokers, a $1 higher cigarette carton price was associated with a 16% higher likelihood of first smoking cessation and an 8% higher likelihood of sustained cessation after controlling for sociodemographic, clinical, behavioral, and policy covariates. Significant associations for first cessation were observed across all education and income subgroups, but results were strongest among participants in the lowest tertile of household income. In contrast, the association of price with sustained cessation was strongest among participants in the highest income tertile. For both outcomes, participants with less than a high school degree were more price sensitive than those with higher educational attainment, as were participants with heavier baseline smoking intensity.

Our results are consistent with several studies using repeat cross-sectional data that reported associations of higher cigarette prices with reductions in current smoking prevalence.[4,6–10,12,14] Our

Table 4. Associations of a $1 Higher Inflation-Adjusted Cigarette Carton Price (in 2000 US Dollars) With Sustained Smoking Cessation,[a] the Coronary Artery Risk Development in Young Adults (CARDIA) Study, 1985–2001, *N* = 1489 Baseline Daily Smokers

	N	Adjusted hazard ratio (95% CI)	*p* interaction[b]
Pooled association[c]			
Model 1: unadjusted	1489	1.07 (1.02 to 1.12)	—
Model 2: adjusted for sociodemographics	1489	1.07 (1.01 to 1.13)	—
Model 3: Model 1 + health behaviors	1489	1.07 (1.01 to 1.13)	—
Model 4: Model 2 + clinical covariates	1489	1.07 (1.01 to 1.13)	—
Model 5: Model 3 + policy covariates	1489	1.08 (1.02 to 1.14)	—
By subgroup (Model 5)[d]			
Average household income[e]			.3
Income tertile 1 (lowest)	505	1.04 (0.88 to 1.22)	
Income tertile 2	501	1.02 (0.92 to 1.13)	
Income tertile 3 (highest)	483	1.15 (1.06 to 1.25)	
Maximum educational attainment			.8
<12 y	142	1.39 (1.00 to 1.93)	
12 y	442	1.05 (0.92 to 1.19)	
13–15 y	559	1.04 (0.95 to 1.13)	
≥16 y	346	1.11 (1.01 to 1.22)	
Baseline smoking intensity			.2
≤10 cigarettes per day	790	1.01 (0.95 to 1.09)	
>10 cigarettes per day	699	1.18 (1.08 to 1.29)	
Presence of a chronic health condition[f]			
Yes	962	1.04 (0.98 to 1.10)	.9
No	527	1.14 (1.04 to 1.25)	

[a]"Sustained smoking cessation" was defined as the first examination or yearly telephone follow-up at which participants reported smoking zero cigarettes per day and continued to report smoking zero cigarettes per day at all subsequent exams/yearly telephone follow-ups (cessation with no relapse).

[b]*p* values are from interaction product terms between price and (1) continuous income, (2) continuous education, (3) continuous smoking intensity, and (4) dichotomous presence of a chronic health condition.

[c]Results are from multivariable extended Cox models and reflect hazard ratios for first smoking cessation associated with a $1 higher cigarette carton price. Model 1 is unadjusted. Model 2 adjusted for baseline age, gender, race, field center, maximum educational attainment, and time-dependent marital status and inflation-adjusted household income. Model 3 additionally adjusted for current alcohol use and physical activity. Model 4 additionally adjusted for body mass index and presence of a self-reported chronic health condition (asthma, hypertension, diabetes, cancer, heart disease). Model 5 additionally adjusted for self-report of a full prohibition on smoking in the workplace, and living in an area with laws banning smoking in all restaurants, bars, and other workplaces.

[d]Subgroup analyses are adjusted for all covariates except the variable used to define the subgroup.

[e]Income tertiles were as follows: tertile 1 = ≤$25 545; tertile 2 = $25 543–$48 539; tertile 3 = ≥$48 540.

[f]Chronic health conditions included hypertension, diabetes, asthma, cancer, and cardiovascular disease. We compared those who ever had a chronic health condition during the follow-up period to those who did not.

results are most directly comparable to the few prior studies that have examined associations with cessation in longitudinal cohorts. Two studies of US young adults found higher state-level cigarette prices to be positively associated with cessation,[17,21] although one study's results did not reach statistical significance.[17] Neither study examined differences by education or income. Similar associations were seen among older adults in the United States[19] and Japan.[20] In the US population, less consistent associations were observed for middle-aged adults (50–64 years), although the reasons for this difference are unclear.[19] In addition, associations were weaker for those with a college degree compared to those with less education, although the difference was not significant.[19] In the Japanese cohort, there were no differences by education or income.[20]

Our study builds upon prior work by examining sustained smoking cessation as well as first cessation. First cessation may reflect an immediate, short-term response to a price increase. However, prior research suggests that smokers attempt to quit many times prior to successful cessation,[36] and prior work in the CARDIA indicates relapse is common,[31] underscoring the importance of examining sustained cessation in addition to first cessation. Our finding that higher cigarette prices were associated with a significantly higher likelihood of both outcomes overall suggests that cigarette prices may influence lasting behavior change among young to middle-aged adults.

Prior findings have been mixed regarding socioeconomic differences in associations of price with smoking outcomes,[6–9,12,14,19,20,26] likely due to wide heterogeneity in study settings and populations. Our finding of stronger price associations with first cessation among the lowest income group consistent with several prior studies among older adults[7] and nationally representative samples with a wide age range,[6,9,14] and may reflect the larger relative economic burden tobacco price increases place on lower income individuals. However, higher cigarette prices were positively associated with first cessation among all subgroups in our analysis, and confidence intervals largely overlapped, suggesting the magnitude of difference was small for this outcome. In contrast, for sustained cessation, results were strongest among those with the highest income. These results suggest that although higher cigarette prices may promote short-term cessation among individuals of all income levels, this does not necessarily translate to sustained cessation among low-income smokers. Lower income smokers may face challenges to cessation that include using smoking to cope with stress, lack of support from health care providers, and higher levels of acceptability of smoking in their community.[37] Our results underscore the importance of considering complementary strategies to cigarette taxation to help lower income individuals quit, for example, supporting access to smoking

cessation aids which may be underutilized or inaccessible to lower income smokers.[38,39]

Strengths of this study include the longitudinal design with annual measurement of smoking status more than 15 years and the geographical diversity of the cohort. In addition, the CARDIA captured detailed information on a variety of potential confounders including sociodemographic characteristics, workplace and legislative smoke-free policies, and health conditions that might predispose participants to quit smoking. This study was also subject to several limitations. First, prices were based on the Cost of Living Index at the county level, core-based statistical area, or state level; although these data provided more granular price exposures than the state-level averages used in most prior studies, they did not reflect within-county variation in prices. As the C2ER attempts to capture consumption patterns of a professional household, prices may not generalize to the purchases of all CARDIA participants. Second, although the number of cigarettes smoked per day was assessed yearly, we did not collect information on whether participants smoked at less-regular intervals (eg, weekend or social smokers) and could not examine associations of cigarette prices with non-daily smoking. Third, self-reported smoking may be subject to misclassification due to recall or social desirability bias; however, prior validation work in the CARDIA suggested misclassification was uncommon (misclassification rate = 4.2%).[40] In addition, as we included 15 years of follow-up, there is the potential for confounding between age and temporal changes in cigarette prices. We adjusted for health conditions that might encourage participants to quit smoking, which is one reason for age-related smoking cessation; however, some residual confounding may remain. Also, it is possible that the price increases observed between 1985 and 2000 would not have as strong an association today, as nicotine dependence may have increased over time among subgroups of the population.[41] Finally, although we controlled for a large number of covariates including legislative smoke-free policies, we cannot rule out the possibility of residual confounding by unmeasured community-level factors (eg, access to smoking cessation resources or educational/advertising campaigns).

Conclusions

Higher cigarette prices were associated with a significantly higher likelihood of first smoking cessation and sustained smoking cessation among a cohort of young to middle-aged adult US daily smokers. Significant associations among all education and income subgroups for first cessation emphasize the potential for cigarette taxation to promote short-term smoking cessation. However, weak associations for sustained cessation among lower income smokers highlight potential challenges in achieving lasting behavior change among this group.

Funding

Declaration of Interests

None declared.

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