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Original Contribution

Impact of Age at Smoking Initiation, Dosage, and Time Since Quitting on Cardiovascular Disease in African Americans and Whites

The Atherosclerosis Risk in Communities Study

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Despite reportedly having less tobacco exposure compared with whites, African Americans account for a disproportionate number of smoking-related deaths. The purpose of this study was to compare the prospective associations between smoking and cardiovascular risk in whites and African Americans. Smoking status was obtained on 14,200 participants from the Atherosclerosis Risk in Communities Study. Incidence of cardiovascular disease (CVD) was ascertained from 1987 through 2007. Adjusted Cox proportional hazard models were used to estimate the CVD incidence associated with smoking behavior. Over 17 years' follow-up, there were 2,777 cardiovascular events. In men, compared with never smoking, current smoking was independently associated with 67% (95% confidence interval (CI): 43, 95) and 72% (95% CI: 30, 126) greater risk of CVD in whites and African Americans, respectively. In women, the smoking-related cardiovascular risk was higher: 136% (95% CI: 88, 196) and 169% (95% CI: 126, 219) in African-American and white women, respectively. Early age at smoking initiation was independently associated with increased risk among all participants irrespective of race. Smoking cessation during follow-up was equally beneficial in both whites and African Americans. African Americans who smoke incur a similar level of cardiovascular risk as white smokers and would derive the same benefits from quitting as whites.

age at smoking initiation; cardiovascular diseases; cigarette smoking; race

Abbreviations: ARIC, Atherosclerosis Risk in Communities; CHD, coronary heart disease; CI, confidence interval; CVD, cardiovascular disease; HR, hazard ratio.

Among Americans, 1 in 5 adults currently smokes, which equates to approximately 45 million smokers of whom 12% are African American (1). Smoking remains a leading cause of morbidity and mortality in the United States with more than 440,000 deaths directly attributed to smoking occurring each year, primarily from cardiovascular disease, respiratory disease, and cancer (2). African Americans account for a disproportionate number of these deaths (3), despite reportedly smoking significantly fewer cigarettes (4) than whites and typically starting smoking later in life (5). Moreover, the years of potential life lost prematurely have been reported to be much higher in African-American, compared with white, smokers (6). For example, a recent economic analysis of the costs of smoking in California reported that the years of potential life lost per death were 16.3 years in African Americans versus 12.5 years in other Californian smokers, respectively (7). The reasons for this mortality differential are unknown but have been suggested to be due, in part, to greater absorption of nicotine and other chemicals per cigarette among African Americans than whites (4).

Although the current prevalence represents a substantial reduction in smoking rates since its peak in the 1950s when more than 50% of men smoked, there is evidence that the decline in smoking rates in the United States has reached a plateau in recent years. For example, between 1997 and 2004, the prevalence of smoking in the United States fell by 15%–21%, but surveillance data from 2009 indicate that there has been no

further decline in smoking rates since then (1). Despite decades of antismoking campaigns, each day in the United States, an estimated 1,000 teenagers become regular cigarette smokers (8).

A US national health objective for 2010 is to reduce the prevalence of smoking in adults to less than 12%, (9), but to date only a few population subgroups (such as Hispanic and Asian women) have reached this goal. More information regarding both the hazards of smoking and the benefits of smoking cessation among different population subgroups may assist in the development of culturally and age-specific smoking cessation programs (10). This is especially true for African Americans for whom there are relatively few data on the harms and benefits of smoking and quitting, respectively (11, 12). Hence, the purpose of this study was to provide information, previously unavailable, as to the strength and nature of the associations among cigarette smoking, quitting, and subsequent risk of cardiovascular disease in African-American and white study participants of a large longitudinal US study with an ethnically diverse study population: the Atherosclerosis Risk in Communities (ARIC) Study cohort.

MATERIALS AND METHODS

Participants and methods

The ARIC Study includes a prospective cohort study of atherosclerotic diseases within 4 US communities: Forsyth County, North Carolina; Jackson, Mississippi; Washington County, Maryland; and the northwest suburbs of Minneapolis, Minnesota. The recruitment of study participants is described in detail elsewhere (13). Briefly, at baseline in 1987–1989, the cohort comprised a probability sample of 15,792 men and women aged 45–64 years. The baseline home interview and clinic examination recorded several cardiovascular risk factors and conditions. Three triennial study visits occurred subsequently, with the last visit in 1996–1998. Additionally, participants or their proxies were contacted annually by telephone to ascertain hospitalizations and deaths through to the end of follow-up in December 2007. In addition, active surveillance of the ARIC Study community hospitals was conducted. The ARIC Study protocol was approved by the institutional review board of each participating university, and informed consent was obtained from each study participant.

Baseline assessment

Questionnaires were used to assess baseline educational level, total annual household income, usual alcohol intake, leisure time sports participation, use of antihypertensive and diabetic medications, and histories of physician-diagnosed diabetes, coronary heart disease (CHD), or stroke. Education was dichotomized as high school diploma or less or as more than high school. In this study, income was classified as up to \$15,999, \$16,000–\$34,999, or $\geq$\$35,000. A sports index, ranging from 1 (lowest) to 5 (highest), was derived from questionnaire items on hours per week spent in up to 4 sports and the months per year each sport was done (14). Three blood pressure measurements were taken with a random-zero sphygmomanometer with the participant seated; the last 2 measurements were averaged. Blood was drawn after an 8-hour fasting period with minimal trauma from an antecubital vein. Glucose and plasma total cholesterol were measured centrally by standard enzymatic methods. The presence of diabetes at study baseline (prevalent diabetes) was defined as a history of, or treatment for, diabetes, a fasting glucose level of 126 mg/dL or greater, or a casual blood glucose level of 200 mg/dL or greater.

Definition of exposure categories

Ascertainment of smoking behavior was obtained by interview at each of the 4 study visits. Additional information on whether the participant was currently smoking or not was recorded at yearly intervals via a telephone interview from the 11th year from baseline. At study baseline, participants were grouped into current, former, and never smokers. For current smokers, the number of cigarettes smoked per day was classified into $<$15, 15–24, 25–34, and $\geq$35 cigarettes per day. Information on age at initiation of smoking was also extracted. Pack-years of smoking at baseline were calculated as the average number of cigarettes smoked per day multiplied by the years of smoking divided by 20 (the number of cigarettes in a standard packet).

In the smoking cessation analysis that incorporated smoking status change during follow-up, individuals were classified as either ''continuous'' smokers or ''new quitters'' (defined as current smoker at baseline but who subsequently went on to quit smoking at some point during study follow-up). Current smokers at baseline with inconsistent smoking status during follow-up (e.g., former smoker at visit 2 but current smoker at a later visit) were classified as continuous smokers. Those individuals who reported to be former smokers or never smokers at baseline were not included in this analysis.

Outcomes

Incidence of cardiovascular disease (CVD) was ascertained through December 2007. Events were ascertained by annual follow-up interview and surveillance of hospital discharges in the ARIC Study areas. Events were validated by abstraction of hospital discharge records and death certificates, followed by classification according to ARIC Study criteria including trained physician reviewers. Out-of-hospital deaths were ascertained through death certificates and, when available, coroner or autopsy reports. Incident CVD comprised incident CHD and stroke. CHD was defined as a validated or definite or probable hospitalized myocardial infarction, a definite CHD death, an unrecognized myocardial infarction defined by electrocardiographic reading, or coronary revascularization (15). A stroke event comprised a validated definite or probable hospitalized ischemic or hemorrhagic stroke confirmed by medical record review.

Statistical analysis

Of 15,689 participants in the ARIC Study at visit 1, 1,489 participants were excluded from the analysis because of ethnicity other than African American or white ($n = 103$), missing values on cigarette smoking status at baseline ($n = 56$),

missing values of covariates ($n = 169$), or self-reported or unclassifiable history of CHD or stroke at baseline ($n = 1,345$) (some individuals were excluded for more than 1 reason), leaving 14,200 for the present analysis. Age-adjusted incidence rates were calculated by using Poisson regression. Cox proportional hazard models with time since visit 1 as the time variable were adjusted for the following: age, sex (where appropriate), study site, race (where appropriate), education, income, usual alcohol intake, sports index, and associated cardiovascular comorbidities including hypertension (defined as systolic blood pressure >140/90 mm Hg and/or antihypertensive medication use), type 2 diabetes, and total cholesterol. Hazard ratios and corresponding 95% confidence intervals for CVD incidence were derived for "former and current smokers" as compared with "never smokers" at study baseline. Hazard ratios and corresponding 95% confidence intervals for dose-response of cigarettes smoked per day were also estimated, taking "never smoked" as the reference group. The assumption of proportional hazards was explored by adding to the model an interaction term between follow-up time and exposure of interest, as well as by inspection of the log (-log(survival function)) curves.

Population attributable fractions for cardiovascular disease due to smoking were calculated as p multiplied by ((hazard ratio (HR) for a category being considered – HR for the reference category)/HR for the category being considered), where p is the proportion of cases that are exposed in whichever category is being considered. To explore the hypothesis that early age at smoking initiation is independently associated with a greater risk of subsequent CVD compared with later age at onset, we stratified current smokers at baseline according to the following age groups corresponding to age at smoking initiation: <12, 13–15, 16–18, 19–21, and ≥22 years (reference group). Cox proportional hazard models that were adjusted for age, sex, the number of cigarettes smoked per day at baseline, and smoking-years as a time-dependent covariate, in addition to those variables previously described, were used to derive the hazard ratios and 95% confidence intervals for CVD by age at smoking initiation.

To estimate the impact of smoking cessation on CVD incidence, we used multivariable pooled logistic regression analysis to derive the odds ratios and 95% confidence intervals for CVD for those smokers who had "newly quit" from study baseline compared with "continuous smokers." Cessation duration was classified according to the year since the individual reported having quit smoking (i.e., 1–3, 4–9, or ≥10 years).

RESULTS

Characteristics of ARIC Study participants at baseline

Of the 14,200 participants at study baseline, 27% were African American. The baseline characteristics of never, former, newly quit, and continuing smokers, stratified by race and sex, are shown in Tables 1 and 2. In men, more African Americans were current smokers compared with whites (38% vs. 24%), whereas approximately a quarter of all African-American women (24%) and white women (25%) were current smokers at baseline. However, among current smokers, white men and women smoked more cigarettes per day compared with African Americans. The prevalence of former smokers at baseline was higher among whites compared with African Americans in both men (47% vs. 33%, respectively) (Table 1) and women (25% vs. 18%) (Table 2). The number of individuals who quit smoking at some point during follow-up translated to 15% with comparable percentages of men and women quitting in both races: 18%, 14%, 15%, and 15% in African-American men, white men, African-American women, and white women, respectively.

Risk of cardiovascular disease in current smokers at baseline

During a mean follow-up of 17.1 years, there were 2,777 cardiovascular events (42% women; 28% African American). The age-adjusted incidence rates for CVD among current smokers at baseline were highest among African-American men and lowest in white women (Table 3). Compared with never smokers, current male smokers had an approximate 70% greater risk of CVD after adjustment for other risk factors, with no evidence of an interaction with race ($P = 0.43$). In women, the risk of CVD in current smokers compared with never smokers was more than doubled and did not differ between African-American and white women ($P_{\text{interaction}}$ for race $= 0.44$) (Table 3). The population fraction attributable to current smoking varied from 10.8% in white men to 22.9% in white women (Table 3). There was a significant dose-response relation between the number of cigarettes smoked per day and risk of CVD, both overall and separately in African Americans and whites with no evidence of an interaction with race ($P = 0.86$) (Table 4). The hazard ratio plateaued at 15–24 cigarettes per day with no increase in risk evident after this level: Overall, compared with never smokers, individuals who currently smoked 1–14 and 15–24 cigarettes per day had 83% and 168% greater risk of CVD, respectively (Table 4).

There was evidence to suggest that age at smoking initiation was independently associated with increased cardiovascular risk (Table 5). Overall, compared with those who started to smoke at 22 years of age or older, individuals who began to smoke at age 12 years or younger had more than 2.5 times the risk of CVD after adjustment for age, sex, the number of cigarettes smoked, the number of smoking-years, and other cardiovascular risk factors ($P_{\text{interaction}}$ for race $= 0.66$).

Risk of cardiovascular disease in former smokers

Among former smokers at baseline, the age-adjusted incidence rates for CVD were comparable to those of never smokers within each of the race and gender groups (Table 3). Compared with never smokers, former smokers had a 17% significantly greater risk of CVD independent of other risk factors. This estimate was similar across the race and gender groups (Table 3). The cardiovascular benefit associated with quitting smoking during follow-up tended to increase with duration of smoking cessation, such that individuals who had quit smoking for more than 10 years had a one-third reduction in cardiovascular risk compared with continuing smokers (Table 6).

DISCUSSION

The cardiovascular hazards of cigarette smoking have been well documented, but the vast majority of the epidemiologic

Table 1. Mean or Prevalence of Age-adjusted Baseline Characteristics According to Smoking Status and Race in Men, ARIC Study, 1987–2007

Characteristic	Never Smokers at Baseline				Former Smokers at Baseline				Continuing Smokers				New Quitters			
	African American (n = 403)		White (n = 1,390)		African American (n = 460)		White (n = 2,198)		African American (n = 275)		White (n = 489)		African American (n = 252)		White (n = 654)	
	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%
Age, years	53 (5.8)		54 (5.7)		55 (6.1)		55 (5.7)		53 (5.9)		54 (5.8)		53 (5.7)		54 (5.4)	
Cigarettes per day[a]									19 (0.6)		28 (0.6)		16 (0.7)		25 (0.5)	
Pack-years of smoking					20 (0.9)		26 (0.4)		34 (1.2)		45 (0.8)		30 (1.2)		40 (0.7)	
Body mass index[b]	28 (0.2)		27 (0.1)		28 (0.2)		28 (0.1)		25 (0.3)		26 (0.2)		27 (0.3)		27 (0.2)	
Systolic blood pressure, mm Hg	130 (1.0)		120 (0.4)		128 (1.0)		121 (0.3)		133 (1.2)		119 (0.7)		130 (1.3)		119 (0.6)	
Total cholesterol, mmol/L	5.5 (0.06)		5.4 (0.03)		5.6 (0.05)		5.5 (0.02)		5.1 (0.07)		5.4 (0.04)		5.3 (0.07)		5.4 (0.04)	
Prevalence																
Antihypertensive medication		35		20		36		21		30		17		26		18
Diabetes mellitus		19		9		17		9		15		9		13		8
Leisure time sports index $\geq$3		22		42		20		43		15		30		19		31
Education less than high school		34		12		44		15		52		27		44		23
Total annual household income $\leq$$15,999		31		7		40		7		58		13		42		9

Abbreviations: ARIC, Atherosclerosis Risk in Communities; SD, standard deviation.

[a] Cigarettes per day in current smokers only.

[b] Body mass index: weight (kg)/height $(m)^2$.

Table 2. Mean or Prevalence of Age-adjusted Baseline Characteristics According to Smoking Status and Race in Women, ARIC Study, 1987–2007

Characteristic	Never Smokers at Baseline				Former Smokers at Baseline				Continuing Smokers				New Quitters			
	African American (n = 1,388)		White (n = 2,893)		African American (n = 416)		White (n = 1,394)		African American (n = 225)		White (n = 594)		African American (n = 352)		White (n = 817)	
	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%
Age, years	53 (5.8)		54 (5.7)		53 (5.6)		54 (5.6)		52 (5.5)		53 (5.7)		53 (5.5)		53 (5.6)	
Cigarettes per day[a]									14 (0.5)		23 (0.5)		11 (0.4)		18 (0.4)	
Pack-years of smoking					14 (0.6)		17 (0.3)		23 (0.7)		34 (0.5)		19 (0.6)		27 (0.4)	
Body mass index[b]	31 (0.2)		27 (0.1)		31 (0.3)		27 (0.1)		28 (0.4)		25 (0.2)		29 (0.3)		25 (0.2)	
Systolic blood pressure, mm Hg	129 (0.6)		118 (0.3)		126 (1.0)		117 (0.4)		129 (1.4)		115 (0.7)		127 (1.1)		113 (0.6)	
Total cholesterol, mmol/L	5.6 (0.03)		5.6 (0.02)		5.6 (0.06)		5.6 (0.03)		5.6 (0.08)		5.7 (0.04)		5.6 (0.06)		5.7 (0.04)	
Prevalence																
Antihypertensive medication		47		26		49		27		46		25		46		23
Diabetes mellitus		20		8		21		7		18		8		16		7
Leisure time sports index $\geq$3		13		26		15		30		13		23		11		25
Education less than high school		36		14		44		13		53		23		42		21
Total annual household income $\leq$$15,999		55		14		57		12		67		25		64		18

Abbreviations: ARIC, Atherosclerosis Risk in Communities; SD, standard deviation.

[a] Cigarettes per day in current smokers only.

[b] Body mass index: weight (kg)/height (m)^2.

Table 3. Cardiovascular Disease Incidence Rate, Hazard Ratio, 95% Confidence Intervals, and Population Attributable Fraction According to Smoking Status at Baseline by Race and Sex, ARIC Study, 1987–2007

Smoking Status at Baseline	No.	%	No. of CVD Cases	IR[a]	95% CI	HR1[b]	95% CI	HR2[c]	95% CI	PAF, %[d]	95% CI
African-American men											
Never	403	29.0	91	14.6	11.9, 18.0	1	Reference group	1	Reference group		
Former	460	33.1	112	15.0	12.5, 18.2	1.04	0.79, 1.37	1.04	0.78, 1.38		
Current	527	37.9	150	21.7	18.5, 25.5	1.55	1.19, 2.01	1.72	1.30, 2.26	17.8	8.7, 25.9
White men											
Never	1,390	29.4	330	14.0	12.6, 15.7	1	Reference group	1	Reference group		
Former	2,198	46.5	604	16.2	14.9, 17.6	1.16	1.01, 1.33	1.13	0.99, 1.30		
Current	1,143	24.2	346	21.4	19.3, 23.8	1.57	1.35, 1.83	1.67	1.43, 1.95	10.8	7.4, 14.1
African-American women											
Never	1,388	58.3	216	9.1	8.0, 10.5	1	Reference group	1	Reference group		
Former	416	17.5	58	8.3	6.4, 10.8	0.92	0.69, 1.23	1.03	0.76, 1.38		
Current	577	24.2	147	17.8	15.2, 21.0	2.03	1.64, 2.50	2.36	1.88, 2.96	20.1	14.1, 25.7
White women											
Never	2,893	50.8	303	5.4	4.8, 6.1	1	Reference group	1	Reference group		
Former	1,394	24.5	156	6.1	5.2, 7.1	1.13	0.93, 1.37	1.29	1.06, 1.57		
Current	1,411	24.8	264	11.5	10.2, 13.0	2.22	1.88, 2.61	2.69	2.26, 3.19	22.9	18.4, 27.2

Abbreviations: ARIC, Atherosclerosis Risk in Communities; CI, confidence interval; CVD, cardiovascular disease; HR1, hazard ratio (model 1); HR2, hazard ratio (model 2); IR, incidence rate; PAF, population attributable fraction.

[a] Age-adjusted incidence rate (per 1,000 person-years).

[b] HR1, age and pack-years adjusted.

[c] HR2, adjusted for model 1 + study site, education, income, usual alcohol intake, sports activity, systolic blood pressure, antihypertensive medication, diabetes, and total cholesterol.

[d] PAF calculated as p multiplied by ((HR2 for current smoking vs. past smoking − 1)/HR2 for current smoking), where p is the proportion of cases among current smokers.

Table 4. Incidence Rates, Hazard Ratios, and 95% Confidence Intervals for Cardiovascular Disease According to the Number of Cigarettes Smoked per Day Among Current Smokers at Baseline, ARIC Study, 1987–2007[a]

No. of Cigarettes per Day[b]	No.	No. of CVD Cases	IR[c]	HR1[d]	95% CI	HR2[e]	95% CI
Overall							
Never smoked	6,074	940	9.0	1	Reference group	1	Reference group
1–14	1,082	230	13.6	1.60	1.13, 2.27	1.83	1.27, 2.62
15–24	1,404	361	17.5	2.19	1.54, 3.11	2.68	1.86, 3.85
25–34	563	143	17.2	2.18	1.49, 3.21	2.65	1.79, 3.91
≥35	534	145	19.6	2.31	1.56, 3.40	2.65	1.79, 3.95
P_{trend}					<0.0001		<0.0001
African American							
Never smoked	1,791	307	10.2	1	Reference group	1	Reference group
1–14	563	143	16.8	1.21	0.69, 2.11	1.40	0.77, 2.54
15–24	397	113	21.0	1.53	0.86, 2.72	1.91	1.05, 3.50
25–34	59	16	20.7	1.33	0.62, 2.82	1.94	0.90, 4.19
≥35	60	16	21.1	1.46	0.68, 3.14	1.84	0.84, 4.01
P_{trend}					0.13		0.016
White							
Never smoked	4,283	633	8.5	1	Reference group	1	Reference group
1–14	519	87	10.3	1.79	1.13, 2.82	2.00	1.25, 3.18
15–24	1,007	248	16.2	2.82	1.81, 4.41	3.21	2.03, 5.06
25–34	504	127	16.9	2.78	1.74, 4.46	3.17	1.97, 5.10
≥35	474	129	19.5	2.90	1.80, 4.67	3.16	1.95, 5.13
P_{trend}					<0.001		<0.001

Abbreviations: ARIC, Atherosclerosis Risk in Communities; CI, confidence interval; CVD, cardiovascular disease; HR1, hazard ratio (model 1); HR2, hazard ratio (model 2); IR, incidence rate.

[a] $P_{interaction}$ by race = 0.44 in model 1 and 0.86 in model 2. P_{trend} was calculated by treating the variable as a continuous variable in the analysis and assigning the median value of cigarettes (i.e., 0, 10, 20, 30, and 40) to each of the categories (never smoked, 1–14, 15–24, 25–34, and ≥35).

[b] Analysis does not include former smokers at study baseline.

[c] Expressed as cardiovascular cases per 1,000 person-years.

[d] HR1 (model 1) includes age, sex, and the number of pack-years.

[e] HR2 (model 2) includes the variables in model 1 plus study site, education, income, usual alcohol intake, sports activity, systolic blood pressure, antihypertensive medication, diabetes, and total cholesterol.

evidence has been derived from either predominantly white or Asian populations, with limited evidence among African Americans. Findings from this current study, which includes a significant number of African Americans, indicate that smoking is as great a cardiovascular hazard among African Americans as whites. Irrespective of race, compared with that among never smokers, the risk of incurring a CVD event was 70% higher among men who smoked, whereas in women, the risk was more than doubled in agreement with previous studies (16). There was also evidence of a dose-response relation with the greatest cardiovascular risk occurring among individuals who smoked between 15 and 24 cigarettes per day (at which point the risk plateaued) compared with never smokers with, again, no evidence to suggest any difference between African Americans and whites.

Our observation that smoking had a comparable effect on cardiovascular risk in African Americans and whites contrasts with those from previous studies, which reported racial differences in the magnitude of the association between smoking and cardiovascular outcomes. For example, the Chicago Heart Association Detection Project in Industry study, which comprised over 3,700 African-American and 33,000 white men and women, reported that, compared with never smokers, African-American male smokers compared with their white counterparts had smoking as a weaker CVD risk factor, although no formal statistical test was performed (hazard ratio (HR) = 1.23, 95% confidence interval (CI): 0.83, 1.82 vs. HR = 1.89, 95% CI: 1.71, 2.09) (17). Racial differences in the duration of cigarette smoking or intensity of smoking habit may have accounted for the weaker effect observed in African-American smokers, who reportedly start smoking later in life and smoke fewer cigarettes than whites (4, 5). However, the authors suggested that competing mortality may have explained the difference, as there was an excess in mortality at younger ages from injury-related causes, namely,motor vehicle crashes and homicides, in African-American compared with white men, thereby reducing African Americans' risk of death from subsequent CVD.

In contrast, data from a combined analysis of the Evans County, Georgia, Heart Study and the Charleston Heart Study suggested that smoking was a stronger risk factor for CHD mortality in African-American than in white men,

Table 5. Incidence Rates, Hazard Ratios, and 95% Confidence Intervals for Cardiovascular Disease Among Current Smokers According to the Age at Smoking Initiation, ARIC Study, 1987–2007[a]

Age at Smoking Initiation, years	No.	No. of CVD Cases	IR[b]	HR1[c]	95% CI	HR2[d]	95% CI
Overall							
≥22	790	175	14.1	1	Reference group	1	Reference group
19–21	794	173	14.0	1.11	0.88, 1.41	1.14	0.90, 1.45
16–18	1,287	319	16.6	1.36	1.08, 1.71	1.28	1.01, 1.62
13–15	570	163	20.5	1.65	1.26, 2.17	1.34	1.01, 1.78
≤12	175	66	32.3	2.70	1.89, 3.86	2.51	1.74, 3.61
P_{trend}					<0.001		<0.001
African American							
≥22	308	79	16.5	1	Reference group	1	Reference group
19–21	236	60	17.0	1.13	0.78, 1.65	1.14	0.77, 1.67
16–18	324	83	18.0	1.23	0.83, 1.81	1.11	0.74, 1.67
13–15	149	48	25.6	1.74	1.09, 2.76	1.32	0.81, 2.15
≤12	66	23	30.4	2.17	1.20, 3.94	1.90	1.03, 3.50
P_{trend}					0.012		0.10
White							
≥22	482	96	12.6	1	Reference group	1	Reference group
19–21	558	113	12.8	1.14	0.85, 1.55	1.14	0.84, 1.55
16–18	963	236	16.2	1.46	1.09, 1.96	1.34	1.00, 1.80
13–15	421	115	18.9	1.64	1.16, 2.31	1.31	0.92, 1.86
≤12	109	43	33.5	3.19	2.03, 5.01	2.87	1.81, 4.55
P_{trend}					<0.001		0.001

Abbreviations: ARIC, Atherosclerosis Risk in Communities; CI, confidence interval; CVD, cardiovascular disease; HR1, hazard ratio (model 1); HR2, hazard ratio (model 2); IR, incidence rate.

[a] $P_{interaction}$ by race = 0.48 in model 1 and 0.66 in model 2. P_{trend} was calculated by treating the variable as a continuous variable in the analysis and assigning the median value of age (i.e., 25, 20, 17, 15, and 11) to each of the categories (≥22, 19–21, 16–18, 13–15, and ≤12 years), respectively.

[b] Expressed as cardiovascular cases per 1,000 person-years.

[c] HR1 (model 1) includes age, sex, and the number of cigarettes smoked per day at baseline, as well as smoking-years as a time-dependent covariate.

[d] HR2 (model 2) includes the variables in model 1 plus study site, education, income, usual alcohol intake, sports activity, systolic blood pressure, antihypertensive medication, diabetes, and total cholesterol.

after adjustment for other traditional risk factors (comparing current with never smokers, relative risk = 2.28, 95% CI: 1.52, 3.44 vs. relative risk = 1.56, 95% CI: 1.23, 1.98), respectively (18). This study, however, was limited by the small number of events among African Americans ($n = 125$ CHD deaths) and by the inability to adjust for tobacco exposure. In contrast, we found no evidence in the ARIC Study cohort to suggest any racial difference in the magnitude of the relation between smoking and subsequent risk of CVD. This finding is based on a much larger number of CVD events among African Americans than in previous studies and, unlike other cohorts, the ARIC Study cohort could adjust for the number of cigarettes smoked per day in addition to other possible confounders.

Early age at smoking initiation has been shown in several prospective cohort and case-control studies to be a risk factor for lung cancer independent of age, sex, and the total number of cigarettes smoked (19, 20). Exposure to smoking in early childhood and adolescence may induce genetic alterations of the respiratory epithelium that subsequently increase the risk of lung cancer in later life (21). Evidence that early smoking onset has a harmful impact on subsequent cardiovascular risk has been less well studied. In this current study, individuals who started to smoke at 12 years of age or younger had more than double the risk of CVD compared with those who started at 22 years of age or older independent of the number of cigarettes smoked per day, the number of smoking-years, and other confounders. This finding is in agreement with data from a pooled analysis of 3 large Japanese cohort studies that reported in age-adjusted analysis, compared with never smokers, those who started smoking at 19 years of age or younger were at greater cardiovascular risk compared with those starting later in life (22). However, this analysis was limited in that the findings were not adjusted for smoking intensity (i.e., cigarettes per day), which may have confounded the relation. In contrast, in an analysis of the Nurses' Health Study, there was a significant inverse trend for total mortality and all smoking-related cancers (both in the unadjusted and adjusted models that included number of cigarettes smoked) with age at smoking initiation but not with cardiovascular mortality (23).

Table 6. Pooled Logistic Regression Analysis for Incidence of Cardiovascular Disease in Relation to Time Since Quitting Smoking by Race, ARIC Study, 1987–2007[a]

	No. of CVD Cases	OR1[b]	95% CI	OR2[c]	95% CI
Overall					
Continuous smoker	940	1	Reference group	1	Reference group
Time since quitting smoking, years[d]					
1–3	76	0.94	0.72, 1.22	0.87	0.67, 1.14
4–9	85	0.95	0.74, 1.23	0.90	0.69, 1.16
≥10	31	0.70	0.47, 1.04	0.67	0.45, 1.01
P_{trend}			0.11		0.061
African American					
Continuous smoker	321	1	Reference group	1	Reference group
Time since quitting smoking, years					
1–3	20	0.80	0.48, 1.35	0.81	0.48, 1.37
4–9	24	0.95	0.58, 1.56	0.93	0.56, 1.54
≥10	10	0.87	0.41, 1.87	0.85	0.39, 1.87
P_{trend}			0.75		0.69
White					
Continuous smoker	619				
Time since quitting smoking, years				61	
1–3	56	0.98	0.72, 1.32	0.89	0.65, 1.21
4–9	61	0.93	0.69, 1.25	0.87	0.64, 1.18
≥10	21	0.63	0.39, 1.02	0.61	0.38, 0.99
P_{trend}			0.076		0.044

Abbreviations: ARIC, Atherosclerosis Risk in Communities; CI, confidence interval; CVD, cardiovascular disease; OR1, odds ratio (model 1); OR2, odds ratio (model 2).

[a] $P_{interaction}$ by race = 0.50. For P_{trend}, values of 0, 2, 7, and 15 years were assigned for continuous smoker and those with quit duration of 1–3, 4–9, and 10 years, respectively.

[b] OR1 (model 1) includes age, sex, race, and cigarette years.

[c] OR2 (model 2) additionally includes study site, educational level, income, usual alcohol consumption, sports index score, systolic blood pressure, antihypertensive medication, diabetes, and total cholesterol.

[d] Analysis does not include former smokers at study baseline and is based on only those individuals who quit smoking during study follow-up.

It is feasible that the inverse relation between age at smoking onset and cardiovascular risk that we, and others, have observed was due primarily to the longer duration of smoking among those who started smoking early in life. Given the strong correlation between age at smoking initiation and duration of smoking, we did not adjust for pack-years at baseline. Instead, we incorporated change in smoking status during follow-up and adjusted for the total number of smoking-years as a time-dependent covariate in the analysis. We therefore consider that this analysis is sensitive enough to distinguish between the effects of early onset of smoking and that due to cumulative tobacco exposure on subsequent vascular risk. This would be of additional concern given the findings of international surveys, which show that in some countries the prevalence of smoking in young adults is on the rise, particularly in women (24) in whom the smoking-related cardiovascular hazards are stronger than in men (16).

Importantly, this study provides information regarding the specific benefits of smoking cessation on CVD risk for African Americans. Compared with continuing smokers, individuals who had quit smoking for a decade or more had a one-third reduction in risk, irrespective of race (although the trend in African Americans was nonsignificant, the test for interaction supported no difference in effect between whites and African Americans). This finding is in agreement with the study by Carnethon et al. (17) who reported that the risk of CVD among African-American and white former smokers was similar to that of never smokers, although no information was given regarding the duration of smoking cessation in that study. Previous studies have reported that African Americans find it harder to quit or to reduce smoking; the provision of race-specific information regarding the hazards and benefits associated with smoking and quitting may assist in the development of smoking cessation aids that specifically target this population subgroup.

Strengths and limitations

The key strengths of this study include its large sample size and the larger number of cardiovascular events (both fatal and nonfatal) among African Americans than in previous cohorts that had reported on the relation between smoking and CVD. Moreover, information on duration and intensity of tobacco smoking enabled a more reliable examination of the relation between smoking and CVD in African Americans than has

previously been possible. However, as with most other cohorts, this study cohort relied upon self-reported smoking habits, as there was no biochemical measure of smoking status, such as cotinine, available in the ARIC Study. Hence, there may have been some misclassification of tobacco exposure with some individuals being classified incorrectly as never smokers or former smokers. However, it is unlikely that this bias would have affected African Americans or whites to a different degree, and therefore although the magnitude of the observed associations may have been diluted, the race comparisons are unlikely to have changed materially. Other limitations include the lack of information on type of cigarette smoked. Previous studies have reported that African Americans prefer high-tar/nicotine and mentholated cigarettes compared with whites (25), which has been suggested to partly account for why African Americans are considered to have a disproportionate burden of smoking-related disease. Finally, as most of the African-American participants were recruited from the Jackson, Mississippi, field center and the whites from the other 3 sites, we cannot preclude confounding of race comparisons by unmeasured factors related to geography.

Summary

In conclusion, the impact of cigarette smoking on CVD is equally as detrimental in African Americans and whites, as to the benefits associated with quitting. The cardiovascular hazard may be even greater in smokers who start as children and adolescents compared with young adults independent of tobacco exposure; this warrants further investigation by future cohorts.

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