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A Case-Control Study of Asphalt and Tar Exposure and Lung Cancer in Minorities

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Abstract

Objectives—Considerable controversy surrounds the carcinogenic potential of asphalt and tar. Since minority individuals may have had relatively high historical exposures, we investigated asphalt and tar exposure and lung cancer risk among African Americans and Latino Americans.

Methods—We conducted a case-control study of lung cancer among African Americans and Latino Americans in the San Francisco Bay area (422 cases, 894 controls). A questionnaire was used to obtain detailed work histories and exposure information. Self-reported exposure to asphalt and tar as well as other factors (eg. smoking, automobile exhaust, and asbestos) were evaluated as predictors of lung cancer risk. Potential effect modification by cytochrome P450 (CYP) 1A1 was also explored.

Results—Self-reported duration of exposure to asphalt and tar was associated with a statistically significant excess risk of lung cancer in the overall population (OR: 1.11, 95%CI: 1.01–1.22), evaluating risk per year of exposure. Years of exposure to automobile exhaust (OR: 1.02, 95%CI: 1.00–1.05) and asbestos (OR: 1.04, 95%CI: 1.02–1.06) were also associated with statistically significant elevations in risk. In Latino Americans, the lung cancer risks associated with polycyclic aromatic hydrocarbon-related exposures were consistently higher in the CYP1A1 wildtype subjects as compared to the variant genotype subjects, and the interaction was statistically significant for smoking and the CYP1A1 M2 polymorphism ($p_{\text{interaction}}=0.02$).

Conclusions—These data are consistent with the literature suggesting that exposure to asphalt and tar may increase risk of lung cancer. However, it was not possible to separate the effects and asphalt and tar in this study.

Keywords

asphalt; tar; lung cancer; minorities

INTRODUCTION

Polycyclic aromatic compounds (PACs) are complex mixtures that result from the incomplete combustion of materials such as coal, oil, gas, wood, or tobacco (ATSDR, 1995). Asphalt, which is derived from petroleum, and tar, which is derived from coal, are both comprised of PACs and have been used in industries such as road paving, roofing, and waterproofing (NIOSH, 2000). Accordingly, workers in these industries have historically been exposed to combinations of unsubstituted polycyclic aromatic hydrocarbons (PAHs), substituted PAHs, and PAH heterocyclic derivatives, many of which are either known or suspected to be carcinogenic (ATSDR, 1995; IARC, 1985; NIOSH, 1998).

Assessment of lung cancer risk associated with exposures to asphalt and tar has been notoriously difficult. Despite a large literature, including a study of almost 30,000 workers from eight different countries (Boffetta et al., 2003a; Boffetta et al., 2003b), there are many factors that complicate the estimation of lung cancer risk associated with occupational exposure to asphalt and tar. Constituents of asphalts and tars vary by source and have changed over time (McClean et al., 2007a; Mundt et al., 2009; Schulte, 2007), workers often have periods of intense exposure followed by periods of no exposure (McClean et al., 2007b), exposures vary significantly both between and within industries (Burstyn and Kromhout, 2000; Burstyn et al., 2000; McClean et al., 2004a; McClean et al., 2004b; McClean et al., 2007a), and there is a clear need to consider co-exposures to other lung carcinogens such as automobile exhaust, asbestos, and smoking (NIOSH, 2000; Schulte, 2007).

It has been suggested that differences in workplace exposure contribute to racial disparity in lung cancer incidence and mortality (Frumkin et al., 1999; Miller and Cooper, 1982; Stewart, 2001). In fact, the occupational medicine literature provides examples where racial differences in cancer mortality led to discovery of workplace exposures that were also segregated by race and explained the increased mortality (e.g. African Americans working topside in coke ovens in the steel industry (Lloyd et al., 1970). This historical situation, then, offers the potential opportunity to investigate particular exposure-associated cancers, such as lung cancer, that have been difficult to assess even in large studies. Accordingly, we have used the resources of a case-control study of lung cancer among minorities, who may have had routine occupational exposures in excess of those experienced by other workers, to investigate the relationship of exposure to asphalt and tar with lung cancer.

MATERIALS AND METHODS

Study subjects

The methods for case and control recruitment have been previously described (Cabral et al., 2003; Wrensch et al., 2005). Primary lung cancers newly diagnosed among San Francisco Bay Area residents between September 1998 and March 2003 were identified through the Northern California Cancer Center (NCCC) rapid case ascertainment program. For the one hospital in the recruitment area that did not participate in the NCCC program, cases were identified by an independent effort that was designed to follow similar procedures. A letter was sent to subjects' treating physicians inquiring whether subjects had any contraindications to participate in the study, and if the response was negative, subjects were sent a letter describing the purpose of the study and a postcard to return for refusal. Subjects who did not refuse participation were telephoned for a short interview to obtain information on ethnicity, prediagnostic smoking history, occupational history, and dietary habits. Subjects who self-identified as Latinos or African-Americans were asked to participate in a more detailed in-person interview and to donate blood or buccal specimens.

Three sources were used to recruit control subjects and included random-digit dialing, Health Care Financing Administration records and community-based recruitment (e.g. health fair, churches and senior centers) (Cabral et al., 2003). Controls were frequency matched to cases on age, sex and race/ethnicity (Latino or African-American) with a control to case ratio of 2 to 1. Participating control subjects were asked to complete in-person interviews and donate a blood and/or buccal specimen. The study was approved by the Committee on Human Research of the University of California, San Francisco (UCSF) and by the Institutional Review Boards of all collaborating institutions.

Blood specimens were obtained by the interviewer-phlebotomist and buccal specimens were self-collected by the subjects at the time of interview. All specimens were stored in foam coolers and transported to the Molecular Epidemiology Laboratory at UCSF within 48 hours. Genotyping for the cytochrome P450 (CYP) 1A1 polymorphism M1 (rs4646903) and M2 (rs1048943) was completed using established polymerase chain reaction (PCR) methods (Ishibe et al., 1997).

Assessment of Occupational Exposures

In-person interviews were conducted using a structured questionnaire and lasted about 2 hours, including detailed information about smoking, work histories, family history of lung cancer, personal medical history, education, household income and other pertinent variables. The questionnaire focused on the period of time prior to diagnosis for cases and prior to interview for controls.

The work histories were designed to assess exposure to 21 different substances for each job held over a lifetime. The assessment of time for each job included year started, year stopped, and information about whether the work was full-time (more than 6 months per year), seasonal (3–6 months per year), or occasional (<3 months per year). Also, for each job, subjects indicated which substances they were exposed to while performing that job.

For jobs that were classified as full-time work, the duration of exposure to each substance was calculated using the years started and stopped data. For jobs that were classified as seasonal or occasional work, subjects were asked to specify the total months worked and this value was used to estimate duration of exposure to each substance. When ‘total months worked’ was not specified for seasonal or occasional work, the duration of exposure to each substance was calculated by dividing the total years of exposure (using years started and stopped) by 2 for seasonal work and 4 for occasional work, calculations that were consistent with the definitions that were provided to subjects. Using this method, an estimate of cumulative exposure duration was calculated for each substance and each subject by summing the substance-specific exposure times for all jobs held during the reported work history.

The substances that are the focus of this paper appeared in the questionnaire exactly as follows: “Asphalt & Tar,” “Automobile Exhaust,” and “Asbestos.” Accordingly, it was not possible to separate asphalt and tar in this study. Automobile exhaust and asbestos were included as potential co-exposures that are also risk factors for lung cancer.

Data Analysis

Questionnaire data were edited twice and problems were resolved. Data were then entered into a database twice, results of double entry compared and discrepancies corrected. All analyses were performed using the entire study population, as well as separately for African Americans and Latino Americans. Logistic regression models were used to estimate odds ratios for exposure to asphalt and tar, automobile exhaust, and asbestos while controlling for age, gender, smoking, and race (except in models stratified by race). Occupational exposures

were evaluated as dichotomous variables (ever/never) as well as continuous variables (years of exposure). Smoking was evaluated as both continuous pack-years and as categorical pack-years (i.e. never smoked, >0–15, >15–36, >36). The odds ratios for combinations of CYP variants with occupational exposure history, as well as tests for interactions, were also determined using logistic regression while adjusting for age, gender, and smoking. The SAS system was used for data management and statistical analyses (SAS Institute, Cary, NC).

RESULTS

Table I summarizes the characteristics of the entire study population (422 cases, 894 controls), as well as separately for African Americans (276 cases, 580 controls) and Latinos (146 cases, 314 controls). As expected, cigarette smoking was a major risk factor in the overall population such that lung cancer risk among participants in the highest smoking category was 11.3 times higher than among never smokers (95%CI: 7.6–17). The smoking-related lung cancer risks were higher among African Americans than among Latino Americans at each level of smoking intensity, though the interaction of smoking and race was not statistically significant ($p\text{-value}_{\text{interaction}}=0.08$). The effect of smoking by race was investigated by adding an interaction term to the model evaluating the overall population (prior to stratification), but the results of that model are not presented since the differences in the effect of smoking are shown in the stratified analyses (Table I).

Refusal rates were comparable between racial groups. Among cases, rates were 7.0% for African Americans and 7.4% for Latinos. Among controls, rates were 14.0% for African Americans and 13.9% for Latinos. The racial characteristics of the study population were primarily dictated by the characteristics of cases identified via the NCCC rapid case ascertainment system, but not the underlying demographics of the San Francisco Bay Area, which is expected given that hospitalized lung cancer cases are unlikely to be representative of all lung cancer cases.

Table II shows the lung cancer risk estimates associated with self-reported exposure to asphalt and tar, as well as for co-exposures to automobile exhaust and asbestos. There were 80 subjects (32 cases, 48 controls) who reported having exposure to asphalt and tar while working in at least one job (Table II). The median start date of first employment in a job in which exposure to asphalt and tar was reported was 1974 for cases (ranging from 1944 to 1995) and 1966 for controls (ranging from 1929 to 1995). In the overall population, estimated lung cancer risks were not significantly elevated for subjects who were ‘ever’ exposed to asphalt and tar as compared to ‘never’ exposed. In stratified analyses, ‘ever’ exposure to asphalt and tar was associated with a statistically significant increase in risk among Latino Americans (OR: 2.9, 95%CI: 1.0–8.5) but not among African Americans (Table II). We also assessed exposure to automobile exhaust, as many have suggested that exposure to diesel fume and automobile exhaust may confound occupational risks associated with asphalt and tar exposures. These risk estimates, while slightly elevated, were not statistically significant. To assess the validity of the self-reported occupational histories, we extracted estimates of exposure to asbestos and assessed the magnitude of lung cancer risk associated with exposure to this known lung carcinogen. As expected, asbestos exposure was associated with a statistically significant increase in lung cancer risk in the overall population (OR: 2.2, 95%CI: 1.6–3.2), a finding that was similar among both African Americans and Latinos.

In an effort to minimally assess a dose-response relationship, we assessed lung cancer risk associated with duration (years) of exposure to asphalt and tar (Table III). Duration of exposure to asphalt and tar was associated with a statistically significant elevation in lung cancer risk (OR: 1.11, 95%CI: 1.01–1.22), interpreted as the increased risk associated with

each year of exposure. The point estimates of this risk were similar for African Americans and Latinos, although not statistically significant once stratified in this way (Table III). Duration of exposure to automobile exhaust (OR: 1.02, 95%CI: 1.00–1.05) and asbestos (OR: 1.04, 95%CI: 1.02–1.06) were also associated with statistically significant increases in lung cancer risk in the overall population. It should be noted that in these analyses, exposure duration was evaluated as a continuous variable such that the risk estimates represent the increased lung cancer risk per year of exposure.

Females were less likely than males to self-report exposure to asphalt and tar (3 of 80 exposed subjects, 4%), automobile exhaust (19 of 87 exposed subjects, 22%), and asbestos (58 of 209 exposed subjects, 28%). The results from analyses of exposure duration restricted to males only (not shown) were almost identical to those shown above for males and females: asphalt and tar (OR=1.10, 0.99–1.21), automobile exhaust (OR=1.02, 0.99–1.05), and asbestos (OR=1.04, 1.02–1.07).

Since we have previously shown that CYP1A1 genotype modifies the lung cancer risk associated with tobacco exposure (Wrensch et al., 2005), we investigated whether similar effect modification was apparent for exposures to asphalt and tar and automobile exhaust (Table IV). In Latino Americans, the lung cancer risks associated with PAH-related exposures were consistently higher in the CYP1A1 wildtype subjects as compared to the variant genotype subjects, though the interaction was only statistically significant for pack-years of smoking and the CYP1A1 M2 polymorphism (OR of 1.06 versus 1.03, p -value_{interaction}=0.02). The lung cancer risks associated with years of exposure to asphalt and tar followed the same pattern, higher among CYP1A1 wildtype subjects (both M1 and M2) as compared to the variant genotype subjects, but these differences were not statistically significant. Similar evidence of effect modification was not observed among African Americans. These findings for occupational exposure to PAHs are consistent with our previous work examining modification of tobacco smoke lung cancer risk (Wrensch et al., 2005).

DISCUSSION

In this case-control study of African Americans and Latino Americans in the San Francisco Bay Area, self-reported duration of occupational exposure to asphalt and tar was associated with a statistically significant increase in lung cancer risk in the overall population. Though the exposed individuals were not divided equally among African Americans (61 subjects) and Latino Americans (19 subjects), the risk estimates associated with exposure duration were almost identical in both subgroups (although not statistically significant when stratified in this way). Statistically significant increases in lung cancer risk were also observed for smoking, automobile exhaust, and asbestos.

Additionally, we found evidence in Latino Americans that CYP1A1 M2 polymorphisms modified the effect of smoking such that lung cancer risks were lower among individuals with CYP1A1 M2 variants than among those who did not carry a variant allele. The effect estimates examining potential modification of exposure to asphalt and tar and automobile exhaust by CYP1A1 were found to be in the same direction as that of smoking, but were not statistically significant. CYP1A1 is induced by PACs (e.g. benzo(a)pyrene) and activates these compounds such that variants of CYP1A1 are more commonly observed to be associated with greater PAH-related lung cancer risk (Guengerich, 1988; Ishibe et al., 1997). However, because the inverse interaction of CYP1A1 variants and PAH-associated lung cancer risk was observed previously in this Latino population (Wrensch et al., 2005), we were interested in investigating other PAH exposures (ie asphalt and tar, automobile exhaust) to see if a similar effect would be observed. The inverse interactions of CYP1A1

variants and PAH-associated lung cancer risk in this Latino population could be due to linkage disequilibrium with an unrecognized lung cancer susceptibility gene. It is possible that the recently admixed genetic structure of the Latino population in northern California may have brought about the unique allelic association that we have observed.

Our findings are consistent with those of previous studies suggesting that occupational exposure to PACs, in particular asphalt and tar and automobile exhaust, may increase risk of lung cancer (Boffetta et al., 2003a; Boffetta et al., 2003b; Bosetti et al., 2007; Garshick et al., 2008; MacArthur et al., 2009). Most notably, Boffetta et al (2003b) conducted a multi-country study of 29,820 male asphalt workers from eight European countries with mortality that was documented from 1953 to 2000. Though the standardized mortality ratio (SMR) of lung cancer among asphalt-exposed workers (SMR: 1.08, 95%CI: 0.99–1.18) was comparable to that of non-exposed workers (SMR: 1.05, 95%CI: 0.92–1.19), the SMR of lung cancer in a sub-cohort of workers who were exposed to asphalt but not coal tar was significantly elevated (SMR: 1.23, 95% CI 1.02–1.48). However, more recently a nested case-control study was conducted using a subset of the same cohort (433 cases and 1,253 controls) to address the limitations of the original study by utilizing improved estimates of exposure to asphalt and confounders such as silica, asbestos, and coal tar (Olsson et al., 2010). Olsson et al. (2010) found no consistent evidence of an association asphalt exposure and lung cancer risk and suggested that the previously observed excess mortality may have been largely due to tobacco consumption and possibly to coal tar exposure.

In a previous study of asphalt paving workers, we found that inhalation and dermal exposures to PACs varied by task and that dermal exposure was strongly associated with urinary 1-hydroxypyrene as a biomarker of internal dose, which also varied by task and increased throughout the work week (McClean et al., 2004a; McClean et al., 2004b). We also found that PAH-DNA adducts exhibited task-based differences and a weekday trend that were consistent with the investigation of absorbed dose in the same population (McClean et al., 2007b). The formation of DNA adducts occurs when reactive metabolites bind to sites within the DNA molecule, providing a useful measure of DNA damage that has been found to be associated with both PAH exposure and lung cancer risk (Tang et al., 1995; Wiencke et al., 1995).

To assess occupational exposures, we relied on self-reported years of employment in jobs that involved exposure to asphalt and tar, automobile exhaust, and asbestos. In other words, if a subject reported having exposure to asphalt and tar while employed in a particular job, duration of employment in that job was used as a surrogate measure of duration of exposure. Self-reported exposure and work histories have been shown to yield valid and reproducible data for use in epidemiologic studies (Delclos et al., 2006; Hobson et al., 2009; Ikin et al., 2002). Additionally, self reported 'ever-never' exposure to asbestos and self-reported duration of exposure to asbestos were both significantly associated with an elevated lung cancer risk in both Latinos and African Americans, again suggesting that the questionnaire data provided a valid measure of historical exposure.

An assumption of this analysis is that length of employment in an exposed-job provides a reasonable surrogate measure for duration of exposure and would therefore be an improvement over simply relying on the ever-never metric, since all ever-exposed subjects are essentially assumed to have had the same exposure whereas duration of exposure allows for some differentiation. Given that a more biologically relevant metric would likely require information about frequency and intensity of exposure (which was unavailable), the use of the ever-never and exposure duration metrics likely resulted in non-differential misclassification, a type of error which leads to underestimation of the true risk.

A strength of this analysis is the availability of individual data for potential confounders (automobile exhaust, asbestos and smoking) in a population of minority individuals who may historically have had relatively high exposure, which allowed us to address common limitations of previous investigations of asphalt and tar (NIOSH, 2000; Schulte, 2007). However, a major limitation of this analysis is that the questionnaire asked about ‘asphalt and tar’ as a single substance, such that it was not possible to disentangle the increased lung cancer risk that may have been attributable to asphalt as compared to that of tar. Tar is derived from coal and contains a higher percentage of PACs than asphalt, which is derived from petroleum. Accordingly, workers exposed to coal tar are more likely to have experienced high exposures to PACs, though the likelihood and intensity of such exposures have varied over time and by sector of the asphalt industry (McClellan et al., 2007a; Mundt et al., 2009). Of the 80 subjects who reported exposure to asphalt and tar, 22 subjects indicated that they worked in road paving, 16 reported that they worked on roofs, and the remaining 42 provided information that was insufficient for determining the nature of the work (e.g. construction, laborer, missing, etc). Accordingly, the limited job description data did not allow for an assessment of lung cancer risk by industry.

We cannot rule out the potential effect of recall bias, since the lung cancer patients may have been more likely than controls to self-report occupational exposures to substances such as asphalt and tar, automobile exhaust, and asbestos. However, for each job in their work history, subjects were asked for fairly objective information: a job description, year started, year stopped, and whether they were exposed to each of 21 substances (yes/no) while employed in that job. Subjects were not asked to provide subjective estimates of exposure intensity. For the 80 jobs reported to have included exposure to asphalt and tar, 60% of the descriptions were consistent with such exposures (i.e. paving, roofing, and/or specifically mentioned working with asphalt or tar), while another 19% provided less specific descriptions that were still consistent with asphalt and tar exposure (i.e. construction, laborer). Since self-reported exposure to asphalt and tar appear to be consistent with the described work for the majority of the reported job descriptions, the greatest potential for recall bias was likely among the remaining 20% of subjects (10 cases, 6 controls) who provided job descriptions that did not have an obvious connection to asphalt or tar (e.g. maintenance, factory worker, missing).

In conclusion, the results of this case-control study are consistent with the literature suggesting that exposure to asphalt and tar may be associated with an increased risk of lung cancer. However, it was not possible to separate the effects of asphalt and tar in this study. The known relationship between smoking and lung cancer and the increasingly recognized association between automobile exhaust and lung cancer were both observed in our case-control study and provide further evidence that occupational exposure to PAC mixtures increase the risk of lung cancer.

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Characteristics of lung cancer cases and controls by race, San Francisco Bay Area Minority Lung Cancer Study, 1998–2003

Table 1

Characteristic	Overall population ^a			African Americans ^b			Latino Americans ^b		
	Controls n (%)	Cases n (%)	Adjusted OR (95% CI)	Controls n (%)	Cases n (%)	Adjusted OR (95% CI)	Controls n (%)	Cases n (%)	Adjusted OR (95% CI)
Total	894 (100)	422 (100)		580 (100)	276 (100)		314 (100)	146 (100)	
Age (yrs)									
<54	218 (24)	84 (20)	1.0	158 (27)	57 (21)	1.0	60 (19)	27 (18)	1.0
>54–64	230 (26)	141 (33)	1.1 (0.8–1.6)	166 (29)	99 (36)	1.2 (0.8–1.8)	64 (20)	42 (29)	1.0 (0.5–1.9)
>64–73	252 (28)	100 (24)	0.8 (0.5–1.1)	154 (27)	68 (25)	1.0 (0.6–1.5)	98 (31)	32 (22)	0.5 (0.2–0.9)
>73	194 (22)	97 (23)	1.0 (0.7–1.5)	102 (18)	52 (19)	1.3 (0.8–2.1)	92 (29)	45 (31)	0.7 (0.4–1.3)
Gender									
Female	477 (53)	219 (52)	1.0	315 (54)	152 (55)	1.0	162 (52)	67 (46)	1.0
Male	417 (47)	203 (48)	0.6 (0.5–0.8)	265 (46)	124 (45)	0.6 (0.5–0.9)	152 (48)	79 (54)	0.7 (0.4–1.1)
Tobacco (pack-years)									
0	352 (39)	57 (14)	1.0	182 (31)	18 (7)	1.0	170 (54)	39 (27)	1.0
>0–15	235 (26)	68 (16)	2.0 (1.3–3.0)	154 (27)	49 (18)	3.3 (1.9–6.0)	81 (26)	19 (13)	1.0 (0.5–1.9)
>15–36	181 (20)	125 (30)	5.2 (3.6–7.7)	145 (25)	92 (33)	7.5 (4.0–12)	36 (11)	33 (23)	4.3 (2.3–7.9)
>36	126 (14)	172 (41)	11.3 (7.6–17)	99 (17)	117 (42)	13.7 (7.8–24)	27 (9)	55 (38)	11.5 (6.1–22)
Race									
African Americans	580 (65)	276 (65)	1.0						
Latino Americans	314 (35)	146 (35)	1.5 (1.2–2.0)						

^a Adjusted for race, age, gender, and tobacco

^b Adjusted for age, gender, and tobacco

Lung cancer risk associated with occupational exposure to asphalt & tar and co-exposures by race, San Francisco Bay Area Minority Lung Cancer Study, 1998–2003

Table II

Exposure	Overall population ^a				African Americans ^b				Latino Americans ^b			
	Controls n (%)	Cases n (%)	Adjusted OR (95% CI)		Controls n (%)	Cases n (%)	Adjusted OR (95% CI)		Controls n (%)	Cases n (%)	Adjusted OR (95% CI)	
Asphalt & tar												
Never	846 (95)	390 (92)	1.0		540 (93)	255 (92)	1.0		306 (97)	135 (92)	1.0	
Ever	48 (5)	32 (8)	1.2 (0.7–2.1)		40 (7)	21 (8)	0.9 (0.5–1.8)		8 (3)	11 (8)	2.9 (1.0–8.5)	
Automobile exhaust												
Never	844 (94)	385 (91)	1.0		541 (93)	251 (91)	1.0		303 (96)	134 (92)	1.0	
Ever	50 (6)	37 (9)	1.5 (0.9–2.5)		39 (7)	25 (9)	1.4 (0.8–2.5)		11 (4)	12 (8)	1.7 (0.7–4.5)	
Asbestos												
Never	786 (88)	321 (76)	1.0		497 (86)	205 (74)	1.0		289 (92)	116 (79)	1.0	
Ever	108 (12)	101 (24)	2.2 (1.6–3.2)		83 (14)	71 (26)	2.2 (1.5–3.2)		25 (8)	30 (21)	2.3 (1.2–4.8)	

^a Adjusted for race, age, gender, smoking, asphalt, automobile exhaust, and asbestos

^b Adjusted for age, gender, smoking, asphalt, automobile exhaust, and asbestos

Lung cancer risk associated with duration of exposure (years) to asphalt and co-exposures by race, San Francisco Bay Area Minority Lung Cancer Study, 1998–2003

Table III

Exposure duration (years) ^a	Overall population ^b				African Americans ^c				Latino Americans ^c			
	Controls		Cases		Controls		Cases		Controls		Cases	
	Mean (SD)	OR (95% CI)	Mean (SD)	Adjusted OR (95% CI)	Mean (SD)	OR (95% CI)	Mean (SD)	Adjusted OR (95% CI)	Mean (SD)	OR (95% CI)	Mean (SD)	Adjusted OR (95% CI)
Asphalt & tar	2.7 (2.8)	1.11 (1.01–1.22)	5.4 (6.3)	1.11 (1.01–1.22)	2.5 (2.6)	1.10 (0.99–1.22)	5.8 (7.2)	1.10 (0.99–1.22)	4.0 (3.7)	1.16 (0.94–1.44)	4.5 (3.3)	1.03 (0.98–1.08)
Automobile exhaust	12 (14)	1.02 (1.00–1.05)	15 (16)	1.02 (1.00–1.05)	11 (14)	1.02 (0.99–1.05)	13 (16)	1.02 (0.99–1.05)	14 (11)	1.03 (0.98–1.08)	18 (16)	1.05 (1.00–1.10)
Asbestos	9.6 (11)	1.04 (1.02–1.06)	11 (12)	1.04 (1.02–1.06)	9.6 (11)	1.03 (1.01–1.06)	10 (11)	1.03 (1.01–1.06)	9.6 (11)	1.05 (1.00–1.10)	13 (13)	

^aThe mean duration (years) is shown for the 'Ever' exposed subjects. For example, the 26% of cases who were 'Ever' exposed to asbestos had a mean exposure duration of 11 years, whereas the 14% of the controls who were 'Ever' exposed had a mean exposure duration of 9.6 years.

^b Adjusted for race, age, gender, smoking, asphalt, automobile exhaust, and asbestos

^c Adjusted for age, gender, smoking, asphalt, automobile exhaust, and asbestos

Odds Ratios for CYP1A1^a variants and PAH^b-related exposures assessing gene-environment interactions by race, San Francisco Bay Area Minority Lung Cancer Study, 1998–2003

Table IV

	African Americans			Latino Americans		
	Wild/Wild OR (95% CI) ^b	Variant ^c OR (95% CI) ^d	p-value for interaction	Wild/Wild OR (95% CI) ^b	Variant ^c OR (95% CI) ^d	p-value for interaction
CYP1A1 M1						
Asphalt & tar (years)	1.11 (0.98–1.25)	1.03 (0.81–1.31)	0.6	1.63 (0.92–2.86)	0.99 (0.71–1.40)	0.1
Automobile exhaust (years)	1.02 (0.98–1.06)	1.02 (0.98–1.07)	0.9	NA	NA	NA
Smoking (pack-years)	1.04 (1.03–1.05)	1.03 (1.02–1.05)	0.5	1.06 (1.04–1.08)	1.03 (1.02–1.05)	0.07
CYP1A1 M2						
Asphalt & tar (years)	NA	NA	NA	1.36 (0.97–1.91)	0.99 (0.69–1.42)	0.2
Automobile exhaust (years)	NA	NA	NA	1.14 (1.00–1.29)	1.00 (0.93–1.08)	0.08
Smoking (pack-years)	1.04 (1.03–1.05)	1.05 (1.00–1.09)	0.6	1.06 (1.04–1.08)	1.03 (1.01–1.05)	0.02

^a CYP1A1=cytochrome P450 1A1

^b PAH=polycyclic aromatic hydrocarbons

^c Includes wild/variant and variant/variant

^d Adjusted for age, gender, smoking, automobile exhaust, and asbestos