Lifetime Cumulative Exposure to Secondhand Smoke and Risk of Myocardial Infarction in Never Smokers

Results From the Western New York Health Study, 1995-2001

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Background: Although many epidemiologic studies have investigated the association between exposure to secondhand smoke (SHS) and risk of coronary heart disease (CHD), few of these studies have assessed exposure measures from different sources over a lifetime. Therefore, we sought to test the association between lifetime cumulative exposure to SHS and risk of myocardial infarction (MI) (as an indication of CHD) among never smokers.

Methods: A population-based case-control study in which participants were 1541 never smokers (284 cases and 1257 controls) drawn from 1197 women and men with incident MI and 2850 healthy controls (aged 35-70 years) identified from 2 Western New York counties between 1995 and 2001. Study subjects were asked to report their exposure to SHS at home, at work, and in public settings from childhood to their present age. Exposure histories from each source were combined to form a cumulative lifetime exposure measure. Multiple logistic regression analysis estimated the association between SHS exposure and case status adjusted for age, sex, education, body mass index, race, drinking status, lifetime physical activity, hypertension, diabetes mellitus, and hypercholesterolemia.

Results: After adjustment for covariates, exposure to SHS was not significantly associated with an increased risk of MI. Compared with participants in the bottom tertile of SHS exposure, those in the top tertile had an odds ratio of 1.19 [95% confidence interval, 0.78-1.82] for MI. Virtually all subjects reported some exposure to SHS over their lifetime, but self-reported exposures declined over time, especially in the period closest to the interview.

Conclusions: Exposure to SHS has declined sharply among nonsmokers in recent years. In the absence of high levels of recent exposure to SHS, cumulative lifetime exposure to SHS may not be as important a risk factor for MI as previously thought.

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THAT ACTIVE SMOKING increases a person's risk of coronary heart disease (CHD) has been well established[1]; therefore, one has good reason to expect that exposure to secondhand smoke (SHS) might also be related to an increased risk of CHD. Over the past 2 decades, a number of studies have reported on the relationship between CHD and exposure to SHS, including several cohort and case-control studies.[2-6] The evidence from these studies, supported by findings from reviews and meta-analyses,[7-10] indicates that exposure to SHS is associated with an increased risk of CHD among never smokers. In addition, data from clinical and animal studies support the biological plausibility of this association.[11-13] However, concerns about uncertainty in the exposure assessment remain, mainly because of methodological difficulties in exposure assessment. Many studies have had to rely on proxy measures of exposure to SHS, such as spousal smoking status, that likely result in misclassification of exposure status.[2-5,14] In addition, few studies[3,4] have attempted to measure exposure from different sources (eg, home and workplace) over time. Because smoking behavior has changed dramatically over the past 50 years, it is likely that exposure to SHS has also changed. This change needs to be considered in exposure assessments, especially for studies examining the risk of CHD in which risk reversal is possible in a short period.[4,15] In this context, recent findings from a study in Helena, Mont,[16] indicate potential short-term beneficial effects on morbidity from CHD during 6 months of smoking bans in the workplace and other public settings. Such results suggest that the effects of SHS exposure on the cardiovascular system may reverse quickly when exposure is removed.

Table 1. Simple Pearson Product Moment Correlation Coefficients Between Secondhand Smoke Exposure–Related Variables*

Variable	Home	Workplace	Public Settings	Total Cumulative
		Women (n = 884)		
Home	1.00	0.16	0.17	0.54
Workplace		1.00	0.25	0.64
Public settings			1.00	0.82
Total cumulative				1.00
		Men (n = 657)		
Home	1.00	0.11	0.14	0.53
Workplace		1.00	0.35	0.75
Public settings			1.00	0.76
Total cumulative				1.00

*Participants were 1541 never smokers in the Western New York Health Study, 1995-2001. All coefficients were significant ($P \leq .01$).

The present study adds to the growing literature on the association of SHS and CHD by presenting data from a large population-based, case-control study that used a comprehensive lifetime assessment method for quantifying exposure to SHS.[17] As such, this study provides a unique opportunity to evaluate how SHS exposures from different sources have changed over time and how risk of CHD (as determined by risk of MI) varies in relation to a measure of lifetime exposure.

METHODS

STUDY DESIGN AND POPULATION

The present study is based on data obtained from a population-based, case-control study among residents, aged 35 to 70 years, of Erie and Niagara Counties in New York State. Data for the overall sample, identified as the Western New York Health Study, were collected between 1995 and 2001 as part of a series of studies specifically directed to examine risk factors for CHD. The details of the overall study design, participant enrollment, and methods have been described elsewhere.[18] The study protocol was approved by the institutional review boards of the University at Buffalo and all of the participating hospitals.

In all, 1197 women and men who were discharged alive with a diagnosis of incident myocardial infarction (MI) (*International Classification of Diseases, Ninth Revision [ICD-9]* code 410) were recruited from hospitals in Erie and Niagara Counties in New York State. The participating hospitals reflect 75% (n=12) of the 16 area hospitals. The 1197 cases represent approximately 64.3% of the identified and eligible cases. The diagnosis of acute incident MI (defined as absence of prior MI, coronary artery bypass graft, percutaneous transluminal coronary angioplasty, symptomatic angina pectoris, or a diagnosis of cardiovascular disease for which diet or drug therapy had been prescribed) was based on the World Health Organization criteria for MI.[19]

Control subjects were randomly selected from among residents of Erie and Niagara Counties who were aged 35 to 70 years and were culled from driver's license lists (for individuals aged ≤65 years) and from lists provided by the Health Care Financing Administration (now known as the Centers for Medicare and Medicaid Services) (for individuals aged >65 years). A total of 2850 controls were interviewed, representing 59.5% of those identified and contacted and for whom we could determine eligibility (absence of prior MI, coronary artery bypass graft, percutaneous transluminal coronary angioplasty, symptomatic angina pectoris, or a diagnosis of cardiovascular disease for which diet or drug therapy had been prescribed).

The present study focuses on 1541 participants who were never smokers (284 cases and 1257 controls). Never smokers were defined as individuals who reported not smoking currently and also reported having smoked fewer than 100 cigarettes in their entire lifetime.

DATA COLLECTION

Eligible cases and controls who agreed to participate were invited to the Center for Preventive Medicine at the University at Buffalo for an interview and physical examination that lasted on average 2.5 hours. Cases were interviewed on average 4.1 months after the clinical event. This time lag from the event was chosen to minimize influences (both biochemical and behavioral) related to the acute clinical event.

During the interview, all participants were queried about their personal medical history, including any physician diagnosis of hypertension, diabetes mellitus, and hypercholesterolemia, and about a number of lifestyle habits, including alcohol consumption and personal smoking history. The reference time frame for questions regarding alcohol consumption habits (to determine drinking status) was the 12 to 24 months prior to the MI (for cases) or the interview (for controls). Hypertension, diabetes, hypercholesterolemia, and smoking status were assessed at the time of the MI (for cases) or the interview (for controls).

Each participant was asked about personal lifetime exposure to SHS in the home, workplace, and other public settings[20] when the participant was younger than 21 years and then for each decade of adult life (21-30, 31-40, 41-50 years old, etc). For SHS exposure at home, we ascertained the number of people living with the participant who smoked cigarettes, cigars, and/or pipes during the specified period ("How many people living with you smoked cigarettes, cigars, and/or pipes?"), as well as the number of years that the participant resided with these smokers ("For how many years did you live with them?"). The answers were used to compute the number of person-years of SHS exposure for each age period. Lifetime cumulative exposure to SHS at home was calculated by summing the number of person-years across each age period.

An estimation of workplace SHS exposure was based on the number of hours per week a participant was exposed to coworkers' cigarette smoke ("Did you have coworkers who smoked cigarettes near you so that you frequently breathed their smoke?") and the number of years of exposure ("If yes, how many hours in a week were you exposed to this smoke?"). The answers were combined to compute the number of cumulative hours of workplace SHS exposure for each of the age periods previously mentioned. Lifetime cumulative exposure to

Table 2. Characteristics of Study Participants*

Characteristic	Women (n = 884)			Men (n = 657)		
	Cases (n = 89)	Controls (n = 795)	*P* Value†	Cases (n = 195)	Controls (n = 462)	*P* Value†
Age, y	59.6 (7.5)	53.5 (10.1)	<.001	55.2 (9.3)	52.2 (10.1)	<.001
Education, y	12.9 (2.1)	13.9 (2.4)	<.001	14.2 (2.5)	14.8 (2.4)	.005
BMI	29.7 (6.2)	28.3 (6.3)	.051	29.1 (4.7)	28.1 (4.6)	.01
Lifetime physical activity, h/wk	4.9 (2.0)	4.8 (1.8)	.64	5.2 (1.7)	5.3 (1.7)	.53
Lifetime cumulative SHS exposure						
Home, person-years	33.4 (26.3)	29.4 (23.7)	.17	31.4 (32.9)	28.6 (37.4)	.35
Workplace, h	11 605.0 (18 168.7)	8073.3 (14 741.5)	.09	23 901.8 (28 485.5)	19 125.6 (25 450.3)	.04
Public settings, times per week	300.8 (178.6)	275.4 (162.7)	.20	379.1 (190.1)	325.5 (184.2)	.001
White race, %	96.6	94.1	.32	94.9	94.6	.88
Hypertension, %‡	57.3	25.7	<.001	43.2	27.4	<.001
Diabetes mellitus, %‡	16.7	6.4	.001	14.9	5.3	.001
Hypercholesterolemia, %‡	45.1	30.4	.006	34.1	26.5	.055
Drinking status, %§						
Lifetime abstainer	23.6	20.5		11.8	7.2	
Not current drinker	41.6	33.9		20.0	19.9	
Current drinker	34.8	45.6	.15	68.2	72.9	.15

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); SHS, secondhand smoke.

*Participants were 1541 never smokers in the Western New York Health Study, 1995-2001. Cases and controls are defined in the "Study Design and Population" subsection of the "Methods" section. Data are presented as mean (SD) unless otherwise indicated.

†Unpaired 2-tailed *t* tests for continuous variables and χ^2 for categorical variables.

‡Indicates a history of hypertension, diabetes mellitus, or hypercholesterolemia before the myocardial infarction (for cases) or the interview (for controls).

§Drinking status refers to alcohol consumption habits during the 12 to 24 months before the myocardial infarction (for cases) or the interview (for controls).

workplace SHS was calculated by summing the responses for each age period.

The estimation of SHS exposure in other public settings was based on the number of times per week in a typical month a participant visited bars, restaurants, social gatherings (eg, dances, parties, or gatherings at friends' homes), or other settings not previously mentioned in which smokers were present. Lifetime cumulative exposure to SHS in other public settings was calculated by summing the responses for each age period.

Because the 3 individual sources of exposure (ie, home, workplace, and public settings) used different units of measurement (ie, person-years for home, hours per week for workplace, and number of times per week in a typical month for public settings), total lifetime exposure to SHS was computed by standardizing the individual cumulative exposure variables for home, workplace, and public settings as *z* scores and summing them. Data for exposure to SHS at home and in public settings were complete for 1539 participants (883 women and 656 men); data for exposure to SHS in the workplace and for total cumulative exposure were complete for 1478 participants (860 women and 618 men).

Table 1 shows the correlation between overall lifetime SHS exposure and cumulative exposure from home, workplace, and public settings by sex. All correlation coefficients were statistically significant ($P \leq .01$); however, the correlations among the specific exposures were weak, whereas total cumulative exposure, as expected, was highly correlated with all 3 sources of exposure.

STATISTICAL ANALYSIS

All analyses were conducted using the Statistical Package for Social Sciences software (SPSS, version 12.0; SPSS Inc, Chicago, Ill). For lifetime total cumulative SHS exposure assessment, the participants were divided by tertiles of SHS exposure based on the distribution of tertiles among the controls, because virtually all of the participants reported some level of exposure. In sex-stratified analyses, the tertiles were based on the distribution in each sex. Participants in the bottom tertile were used as the reference category. To approximate relative risk, adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were calculated using multiple logistic regression models controlling for the following covariates: age, sex (in combined analyses), education, body mass index, race, drinking status, lifetime physical activity, hypertension, diabetes, and hypercholesterolemia. Test results for the interaction between selected covariates and SHS exposure variables were not significant.

To evaluate temporal trends in exposure to SHS, we computed a measure of the prevalence of self-reported exposure (ie, those not exposed vs those exposed) from each exposure source (ie, home, workplace, and public settings) for each age period (eg, at home before age 21 years, at home between ages 21 and 30 years, at home between ages 31 and 40 years, and so forth). For the assessment period closest to the time of the interview, the exposure time frame varied by the subject's age. For example, for someone aged 55 years, the exposure period assessment was from ages 51 to 55 years. To assess temporal trends in the prevalence of exposure to SHS across the different age periods and from different sources, we constructed 4 birth cohorts as follows: individuals born between 1930 and 1939, 1940 and 1949, 1950 and 1959, and 1960 and 1969.

RESULTS

Selected characteristics of study participants who were never smokers are displayed in **Table 2** for cases and controls by sex. For both sexes, cases were significantly older than controls (by 6.1 years for women and 3.0 years for men). For both sexes, all lifetime SHS exposures were higher in cases than in controls; however, statistical significance was reached only for lifetime cumulative exposure to SHS in the workplace and other public settings in men.

Table 3 gives results of the fully adjusted logistic regression models for lifetime cumulative exposure to SHS for men and women separately and combined. After adjustment for covariates, SHS exposure was not significantly associated with the risk of MI. Combined analyses, comparing participants in the top tertile vs those in the bottom tertile of SHS exposure, yielded an OR of 1.19 (95% CI, 0.78-1.82).

We attempted to take into account the potential influence of the sharp decline in exposure to SHS by evaluating the risk of MI in participants with high and low SHS exposure reported for the age period closest to the time of the interview. In the combined analyses, which compared participants with high levels (greater than the median) of SHS exposure (either distant or recent) vs participants with low distant and low recent exposure (less than or equal to the median) yielded an OR of 0.96 (95% CI, 0.60-1.55) in the fully adjusted model (data not shown).

Table 4 shows the self-reported prevalence of SHS exposure (ie, those not exposed vs those exposed) for the home, workplace, and public settings over one's lifetime compared with the most recent assessment period. All but 3 subjects in the study reported some exposure to SHS over their lifetime, but self-reported exposures declined sharply in both men and women for the most recent assessment period for home and the workplace; self-reported exposure to SHS remained high in public settings. More than three quarters of subjects reported exposure to SHS at home before age 21 years. Exposure to SHS at home during adulthood varied by sex, with women more likely than men to report exposure (58% vs 46%, $P<.001$).

Figure 1 and **Figure 2** display the temporal changes in exposure to SHS in the home, workplace, and public settings by birth cohort. We found evidence of declining trends in the prevalence of SHS exposure for both sexes and for all 3 sources, although these declines were not as sharp for public settings; these trends occurred across all birth cohorts.

Table 3. Odds Ratios and 95% Confidence Intervals for Lifetime Cumulative Exposure to SHS and Risk of MI

Total Cumulative SHS Exposure, *z* Score	No. of Subjects (No. of Cases/Controls)	Fully-Adjusted OR (95% CI)*
Women		
Tertile†		
First	285 (25/260)	1.00
Second	280 (21/259)	0.50 (0.25-1.04)
Third	295 (35/260)	0.67 (0.34-1.31)
P value for linear trend	. . .	.30
Men		
Tertile‡		
First	193 (45/148)	1.00
Second	196 (47/149)	0.93 (0.55-1.58)
Third	229 (81/148)	1.40 (0.80-2.43)
P value for linear trend	. . .	.22
All Participants		
Tertile§		
First	470 (62/408)	1.00
Second	463 (55/408)	0.69 (0.44-1.09)
Third	545 (137/408)	1.19 (0.78-1.82)
P value for linear trend	. . .	.28

Abbreviations: CI, confidence interval; MI, myocardial infarction; OR, odds ratio; SHS, secondhand smoke; ellipses, not applicable.
*Adjusted for age, sex (in combined analyses), education, body mass index, race, drinking status in the past 12 to 24 months, physical activity, hypertension, diabetes mellitus, and hypercholesterolemia (before the MI [for cases] or the interview [for controls]). For female and male participants, tertiles are sex-specific.
†Complete data were available for 860 participants.
‡Complete data were available for 618 participants.
§Complete data were available for 1478 participants.

Table 4. Prevalence of SHS Exposure From Different Sources for Different Age Periods of Assessment*

Variable	Women (n = 884) Lifetime	Women (n = 884) Childhood (Age, <21 y)	Women (n = 884) Adulthood (Age, ≥21 y)	Women (n = 884) Most Recent Period†	Men (n = 657) Lifetime	Men (n = 657) Childhood (Age, <21 y)	Men (n = 657) Adulthood (Age, ≥21 y)	Men (n = 657) Most Recent Period†
Home‡								
Not exposed	134 (15.2)	236 (26.7)	373 (42.2)	768 (87.0)	130 (19.8)	182 (27.7)	355 (54.1)	580 (88.4)
No. of cases/controls	11/123	25/211	29/344	78/690	39/91	53/129	104/251	177/403
Exposed	749 (84.8)	647 (73.3)	510 (57.8)	115 (13.0)	526 (80.2)	474 (72.3)	301 (45.9)	76 (11.6)
No. of cases/control	78/671	64/583	60/450	11/104	156/370	142/332	91/210	18/58
Workplace§								
Not exposed	301 (35.0)	. . .	. . .	767 (89.2)	137 (22.2)	. . .	. . .	473 (76.5)
No. of cases/controls	29/272	. . .	. . .	72/695	39/98	. . .	. . .	141/332
Exposed	559 (65.0)	. . .	. . .	93 (10.8)	481 (77.8)	. . .	. . .	145 (23.5)
No. of cases/controls	52/507	. . .	. . .	9/84	134/347	. . .	. . .	32/113
Public settings‡								
Not exposed	8 (0.9)	. . .	. . .	148 (16.8)	5 (0.8)	. . .	. . .	100 (15.2)
No. of cases/controls	1/7	. . .	. . .	24/124	2/3	. . .	. . .	35/65
Exposed	875 (99.1)	. . .	. . .	735 (83.2)	651 (99.2)	. . .	. . .	556 (84.8)
No. of cases/controls	88/787	. . .	. . .	65/670	193/458	. . .	. . .	160/396

Abbreviations: SHS, secondhand smoke; ellipses, not determined.
*Participants were 1541 never smokers in the Western New York Health Study, 1995-2001. Data are presented as number (percentage) of participants unless otherwise indicated.
†Prevalence of SHS exposure (ie, those exposed vs those exposed) estimated for the most recent assessment period based on the subject's age.
‡Complete data were available for 883 women and 656 men.
§Complete data were available for 860 women and 618 men.

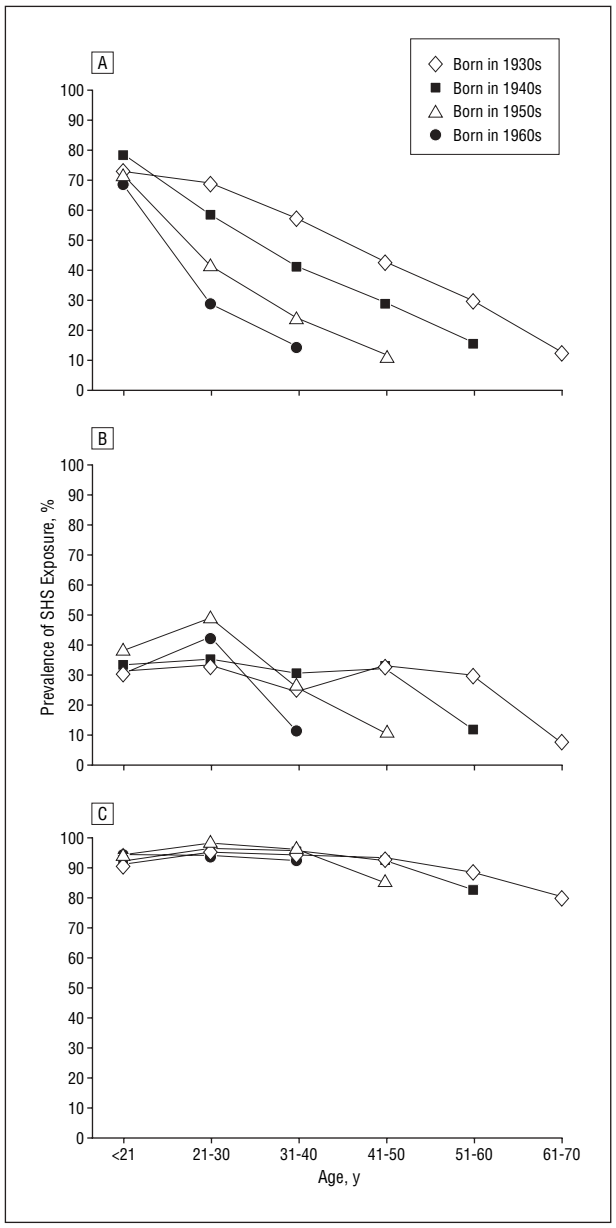

Figure 1. Prevalence of exposure to secondhand smoke (SHS) in the home (A), workplace (B), and public settings (C) throughout life for 884 women in the Western New York Health Study, 1995-2001, by birth cohort.

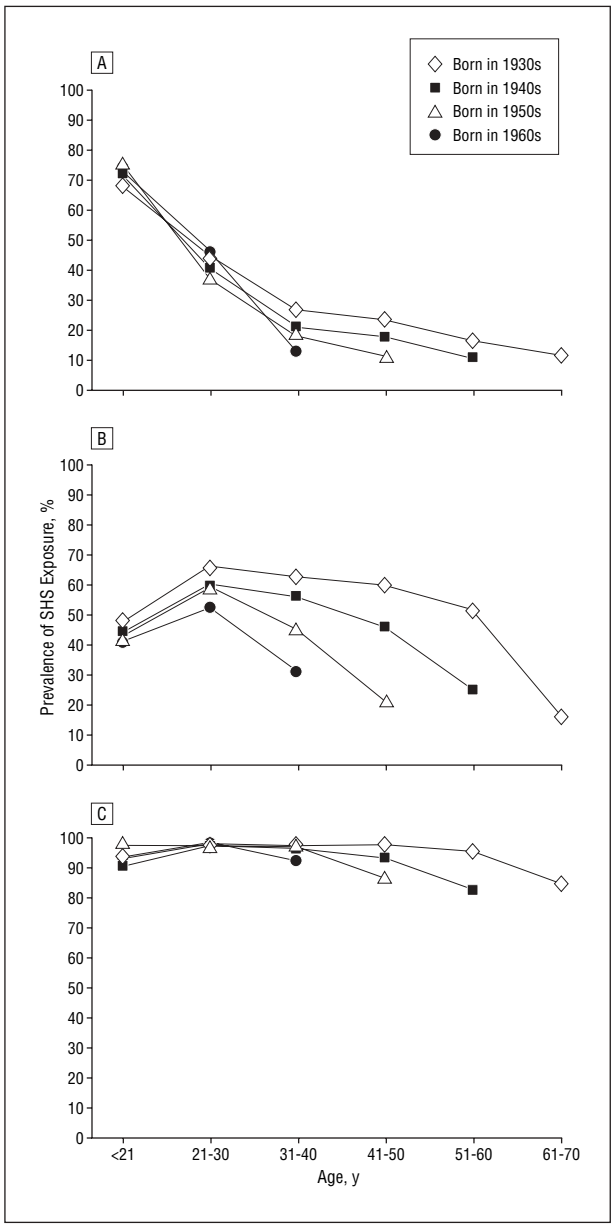

Figure 2. Prevalence of exposure to secondhand smoke (SHS) in the home (A), workplace (B), and public settings (C) throughout life for 657 men in the Western New York Health Study, 1995-2001, by birth cohort.

COMMENT

This study failed to find a strong and consistent association between lifetime exposure to SHS and the risk of MI. While not reaching statistical significance ($P<.05$), the overall OR for low vs high exposure to SHS was 1.19 (95% CI, 0.78-1.82), which is consistent with the magnitude of association observed in other epidemiologic studies.[7-10] This estimate is likely reduced by misclassification bias in our measurement of exposure to SHS and because the lowest exposure category included subjects with some level of SHS exposure. In particular, the questions we used to measure exposure to SHS at work counted subjects who did not work adjacent to persons who smoked regularly as being unexposed; those who were not employed did not have workplace exposure to report. We believe this approach likely caused us to underestimate workplace exposure for some subjects, although we have no reason to believe that this measurement error was greater for cases than for controls. The effect of nondifferential misclassification would be to drive our estimate of the true relative risk toward the null value and would lower the statistical power of our study.[21] Given this nondifferential misclassification and the relatively small OR expected (approximately 1.3), this study could have been limited by the number of cases included in the analysis, particularly among women.

In addition, our ability to show a relationship between exposure to SHS and risk of MI may have been compromised by the dramatic decline in exposure to SHS that took place among our study subjects.

Although virtually all subjects in the study reported some exposure to SHS over their lifetime, self-reported exposures declined sharply over time to a point where only a small percentage of subjects reported any exposure to SHS at home or at work during their most recent assessment period. The reported decline in exposure to SHS mirrors national declines in smoking prevalence and increases in the adoption of smoke-free workplace policies.[22-28] In the absence of high levels of recent exposure to SHS, cumulative lifetime exposure to SHS may not be as important a risk factor for MI as previously thought. Support for this view is found from studies evaluating risk reduction associated with the cessation of smoking, such as Doll et al,[15] in which cessation reduced the risk of MI to the level of nonsmokers within a few years. In this context, findings from a recent observational study[16] conducted in Helena, Mont, point to the potential benefits (in terms of reduced risk of CHD) that may follow the implementation of a smoking ban in public settings. In that study, hospital admissions for acute MI decreased by about 40% during a 6-month smoking ban in the workplace and other public settings; however, the admission rates returned to baseline levels after the ban was reversed. In Pueblo, Colo, Bartecchi et al[29] recently reported a 27% decline in incidence of MIs 1½ years after enactment of a comprehensive citywide smoke-free ordinance. However, more research is needed to better understand how the risk for MI changes over time after SHS exposure is eliminated or reduced.

The evidence from laboratory and animal studies[10-12] pointing to a causal association between SHS exposure and risk of CHD is overwhelming; therefore, we think that our null finding in this study does not diminish such evidence. On the contrary, recent experimental data[30,31] suggest that the pathophysiological mechanisms underlying the detrimental effects of SHS exposure on the cardiovascular system may act in an acute fashion as well. Thus, the failure to show an association between SHS exposure and CHD in the present study may reflect the protective effects of tobacco control efforts that have markedly reduced SHS exposure.

We think that the lifetime exposure assessment method we used did not adequately capture the short-term effects of exposure to SHS and may have contributed to the null association we observed. We recommend that future epidemiologic studies investigating the link between SHS exposure and cardiovascular disease focus more attention on assessing exposure in the recent past (say, 5-10 years). Given the declining trends in smoking in many western nations, epidemiologic studies may have a reduced ability to show a clear-cut relationship between SHS exposure and risk of CHD. In fact, most of the recent studies[5,6] positively linking SHS exposure and risk of CHD have come from countries where smoking prevalence is still high and thus where exposure to SHS would also be expected to be significant.

In summary, it may be difficult for epidemiologic studies to show a relationship between measures of lifetime exposure to SHS and risk of CHD in locations where exposure levels are declining sharply. The fact that exposure to SHS is declining is a positive development that is likely to contribute to reductions in mortality from CHD.

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