JACC Vol. 31, No. 1
January 1998:1–9

REVIEW ARTICLE

Heart Disease From Passive Smoking in the Workplace

A. JUDSON WELLS, PHD

Kennett Square, Pennsylvania

Objectives. **This review sought to determine whether passive smoking in the workplace has roughly the same association with heart disease as passive smoking at home and to update a previous 1994 review on the effects of home-based passive exposure on the heart.**

Background. **To predict the effects of passive smoking at work on heart disease, public agencies have had to assume that workplace exposure to tobacco smoke was equivalent to home exposure. With the availability of more workplace exposure data, it is now possible to make a direct comparison.**

Methods. **The odds ratios and relative risks (RRs) of the eight studies that contained data on workplace exposure (1,699 cases) were arranged in what was believed to be the order of the quality of their tobacco smoke exposure measurements. A meta-analysis was performed to obtain combined RRs. Data from seven new studies on largely home-based exposure and heart disease that were not included in the 1994 review were also evaluated.**

Results. **The combined RR for the three top-rated workplace studies was 1.50 (95% confidence interval [CI] 1.12 to 2.01). Adding four lower rated studies reduced the RR to 1.35 (95% CI 1.09 to 1.67). Adding the largest study but the one with questionable exposure history reduced the combined RR to 1.18 (95% CI 1.04 to 1.34). Adding the seven new, largely home-based studies increased the home-based morbidity RR to 1.49 (95% CI 1.29 to 1.72) compared with 1.42 in 1994 while leaving the mortality RR unchanged at 1.23 (95% CI 1.14 to 1.32).**

Conclusions. **The RRs for heart disease from passive smoking at work are roughly equal to those from home-based exposure.**

(J Am Coll Cardiol 1998;31:1–9)

There have been several reviews of the effects on heart disease of exposure to environmental tobacco smoke (ETS), either from spousal smoking or from the smoke of others (1–7), but there has been no published overall review of epidemiologic studies of the effects of workplace exposure on heart disease. The effects on heart disease of exposure to ETS at the workplace are important, not only for public policy reasons, but because the results are less likely to be subject to potential confounding from lifestyle factors that might affect home-based results. Since my previous review in 1994 (1), seven new studies (8–14) of passive smoking and heart disease have appeared, four of which (9,10,12,13) contain data on workplace exposure and are included in the present analysis. An update of the 1994 review (1) of heart disease and exposure to ETS for all types of exposures and including the new studies is presented in the Appendix.

Methods

All known published studies that contained data on heart disease and exposure to ETS at the workplace were considered for inclusion. Workplace results based on >50% surrogate responses were rejected because it is thought that surrogates do not have sufficiently accurate recall of a subject's likely workplace exposure. The only workplace results excluded from the present analysis are those of Jackson (15) for cardiac death, where 100% of the case responses were from surrogates. In general, where two or more workplace risks were available from a particular study, the risk was chosen for exposure with or without other ETS exposure. In other words, the workplace exposure was looked on as an added exposure to whatever else the subject had been exposed to. Also, the risk was chosen for which the maximal number of adjustment factors had been used and which was thought to have the least tendency for exposure misclassification.

Odds ratios (ORs) from case-control studies were assumed to be reasonable approximations to relative risks (RRs) because most of the case-control studies met the criteria of Breslau and Day (16), except for Muscat et al. (12), where data were collected over a 10-year period. Combined RRs were obtained by calculating weighted log means of the ORs or RRs from any appropriate group of studies. According to Rothman (17), the statistical weight for any specific ln(OR) or ln(RR) was assumed to be the inverse of its variance (or standard deviation squared), which in turn was usually calculated from the individual confidence limits (CLs) of the 95% confidence interval (CI) [Weight = $(2 \times 1.96)^2/(\ln CL_{upper} - \ln CL_{lower})^2$] or, when necessary, from chi-values developed from the cell counts [Weight = $(Chi/\ln RR)^2$]. For some of the studies, ORs or RRs plus CIs were available only for two or three different levels of exposure. To arrive at a single OR or RR and weight in these instances, the weights calculated for the individual exposure levels were summed, but because this involved multiple use of the no-exposure level, the sum was reduced by a fraction that was determined from other studies (10,18,19 and

Manuscript received September 16, 1996; revised manuscript received April 11, 1997, accepted September 25, 1997.

Address for correspondence: Dr. A. Judson Wells, 5 Ingleton Circle, Kennett Square, Pennsylvania 19348.

0735-1097/98/$19.00
PII S0735-1097(97)00432-4

Abbreviations and Acronyms

CHD = coronary heart disease
CI = confidence interval
CL = confidence limit
ETS = environmental tobacco smoke
OR = odds ratio
RR = relative risk

Morabia A, personal communication, January 1997) in which CIs for both individual levels and the combined exposure were known, and the corresponding weights could be determined. It was found that the reductions were a function of the fraction of the control subjects who were unexposed. For two levels of exposure, the reductions varied from 12% for 80% unexposed to 45% for 20% unexposed. For three levels, the reductions were slightly higher. No attempt has been made to correct the risks for smoker misclassification. This correction was found to be small in the earlier review (1). The correction depends on the tendency for smokers to marry smokers, which does not apply to the workplace, and the correction cannot be estimated for some of the new studies in which the mix of male and female subjects is not provided.

In the earlier review (1), studies were assigned a quality tier level related to the number of other heart disease risk factors that had been used to adjust the OR or RR because possible confounding by lifestyle factors was a concern relative to the largely home-based risks. For workplace risks there is greater concern about possible errors in measuring the level of exposure than there is about possible confounding by lifestyle factors. Factors that were thought to influence the quality of the studies were passive smoking history, prevalence of current smokers (of the same gender as the subjects) in the population, whether the subjects in the reference category included only those employed, years of follow-up for the prospective studies, time span for collection of data for the case-control studies and adjustment for other heart disease risk factors. Using these factors, with special emphasis on the history of passive smoking exposure, tier levels one (highest quality) through four were assigned to the workplace studies, which were then arranged in that order in the tables.

Results

Descriptions of the individual studies containing data for heart disease and workplace exposure to ETS are shown in Table 1. The RRs for the individual studies and the combined RRs are shown in Table 2. The top-rated study in Table 1 is that of He et al. (9) who studied women in Xian, China. It focused primarily on workplace effects, with an excellent history of workplace exposure, including the number of cigarettes/day smoked by co-workers, duration of exposure in years, number of co-workers who smoked and daily exposure time in hours. Passive smoking was defined as working with co-workers who smoked in the same unit for >5 years. Smoking prevalence among women in Xian is only 8.6%, whereas most men smoke. However, because of the Oriental culture, other than their husbands and possibly other male relatives, nonsmoking women would be exposed to very few men outside the workplace. Therefore, the background effects of ETS should be minimal. All the women studied were full-time employees. The possible confounding effect of other heart risk factors was thoroughly evaluated.

The next study presented in Table 1 is that by Kawachi et al. (10) from the well known Nurses' Health Study, which has been conducted over many years by Harvard Medical School and the Harvard School of Public Health. Passive smoking was defined as current exposure to cigarette smoking at work but was measured only at enrollment in 1982. This study provides two levels of ETS exposure (occasional and regular) and adjusts for a large number of heart disease risk factors.

The study by Butler (18) is a published doctoral dissertation. Subjects were asked whether they had worked in the same room with someone who smoked and, if so, for how many years? There were a small number of long-term ex-smokers included among the nonsmokers in the cohort, but it was expected that they would have little effect on the workplace passive smoking RR. The cohort consisted of Seventh Day Adventists, who are proscribed from smoking by church rules. Current smoking prevalence was 2.1% among the men and 1.1% among the women, indicating low background effects of ETS. However, the RRs were adjusted only for age.

There is little to choose from among the next four studies (12,15,20,21). None reported any passive smoking history other than exposed or not exposed, nor were many heart risk factors considered other than age. The cohort for the study by Svendsen et al. (20) consisted of men at high risk for heart disease. Subjects were asked whether most of their co-workers smoked. The study by Jackson (15) was published only as a doctoral dissertation. Subjects exposed to ETS during tea breaks were included among the nonexposed. The study by Muscat and Wynder (12) was conducted in four hospitals in the northern United States. They apparently measured years of exposure but reported only current exposure. The study by Dobson et al. (21) may be the weakest of the studies. It provides no breakdown for surrogate versus direct interviews, no information on the proportion of fatal versus nonfatal cases and no definition of passive smoking.

Because of its very large size, The American Cancer Society study analyzed by Steenland et al. (13) is shown separately so that its results can be compared with the combined results of all the other studies. Its questionnaire (personal communication, American Cancer Society, 1981) was administered by American Cancer Society volunteers. It had only a single, simple passive smoking question, namely, "Whether or not you smoke, on the average, how many hours a day are you exposed to cigarette smoke of others: At home__, At work__, In other areas__." Many of the never-smoking respondents failed to answer these questions and were excluded from the analysis. Specifically, 28.2% of men and 48.4% of women failed to answer the workplace question, whereas some respondents

Table 1. Epidemiologic Studies of Heart Disease and Passive Smoking in the Workplace

Study (ref no.)	Locale	Study Type	Population: No. of Cases M	Population: No. of Cases F	Population: No. of Control Subjects M	Population: No. of Control Subjects F	Fatal or Nonfatal	Passive Smoking History	Current Smokers [% (M/F)]	Ref Category: Workers Only	Follow-Up (yr) (pros)	Data Collection (yr) (C/C)	Other Adjustment Factors	Quality Tier Assigned*
He et al. (9)	China	C/C	—	59	—	126	nf	d, c, n, h	8.6	Yes	—	3	A, B, C, D, FH, FIHD, E, HC, MS, O, P, S, W, X	1
Kawachi et al. (10)	USA	Pros	—	64	—	32,046†	nf	o, r	29	?	10	—	A, AL, AS, B, C, CA, D, ES, FIHD, FO, FT, MI, MN, OC, ST, VE, W, X	2
Butler (18)	Calif	Pros	75	70	2,345	4,122	f	d	2.1/1.1	No	6	—	A	3
Svendsen et al. (20)	USA	Pros	69‡	—	1,237	—	f+nf	—	72	Yes	8	—	A	4
Jackson (15)§	NZ	C/C	28	8	114	97	nf	—	20/24	No?	—	2	A, MI, SS	4
Muscat and Wynder (12)	No. USA	C/C	68	35	108	50	nf	—	?	Yes	—	10	A, B, E	4
Dobson et al. (21)	Australia	C/C	75	17	205	197	f+nf	—	25/16	Yes	—	1.4	A, MI	4
Subtotal			335	277										
Steenland et al. (13)‖	USA	Pros	768	319	75,237	108,302	f	—	29/24	Yes	7	—	A, AL, AR, AS, B, D, DU, E, ES, MI, W, X	—
Total			1,103	596										

*Tier 1 is highest quality; tier assignment is based primarily on quality of passive smoking history, secondarily on the other factors in the table. High smoking prevalence is adverse because of high environmental tobacco smoke background; a reference category of workers only is favorable; and shorter years of follow-up or data collection are favorable. †Includes nonemployed women. ‡Includes 13 fatal cases. §Jackson (personal communication, 1993) advises that some of these cases and control subjects were later found to be ineligible, but the odds ratios are correct. ‖Cases and populations include workers >65 years old. A = age; AL = alcohol use; AR = arthritis; AS = aspirin use; B = blood pressure or hypertension; c = cigarettes/day; C = cholesterol; CA = cancer; Calif = California; C/C = case-control; d = duration (yr); D = diabetes; DU = diuretic drug use; E = education; ES = estrogen use; f = fatal; F = female; FH = family history of hypertension; FIHD = family history of ischemic heart disease; FO = father's occupation when subject was age 16; FT = saturated fat intake; h = hours/day; HC = high density cholesterol; HSM = husband's smoking; M = male; MI = personal history of myocardial infarction; MN = menopausal status; MS = marital status; n = number of smokers; nf = nonfatal; No. = northern; NZ = New Zealand; o = occasional exposure; O = occupation; OC = oral contraceptive use; P = personality type; Pros = prospective; r = regular exposure; ref = reference; S = stress; SS = social status; ST = stroke; VE = vitamin E intake; W = weight or body mass index; X = exercise; — = not applicable or no data.

Table 2. Odds Ratios and Relative Risks for Heart Disease and Passive Smoking in the Workplace

Study (ref no.)	Adjusted OR or RR (95% CI)	Statistical Weight	Dose Response	
			Intensity	Duration
He et al. (9)	1.85 (0.86–4.00)	6.5	0.87, 2.95, 3.56*, 1.16, 5.06, 4.11‡, 0.62, 4.03, 21.32§	3.08, 1.56†
Kawachi et al. (10)	1.68 (0.81–3.47)	7.3	1.49, 1.92‖	
Butler (18)				
Men	1.02 (0.61–1.70)	14.6	—	1.26, 0.76¶
Women	1.85 (1.13–3.02)	16.0	—	1.85, 1.86¶
Svendsen et al. (20)	1.4 (0.8–2.5)	11.8	—	—
Jackson (15)				
Men	1.8 (0.8–4.3)	5.1	—	—
Women	1.1 (0.2–5.8)	1.4	—	—
Muscat and Wynder (12)				
Men	1.2 (0.6–2.2)	9.2	—	—
Women	1.0 (0.4–2.5)	4.6	—	—
Dobson et al. (21)				
Men	0.95 (0.51–1.78)	7.5	—	—
Women	0.66 (0.17–2.62)	2.1	—	—
Subtotal				
Men	1.19 (0.90–1.58)	48.2		
Women	1.58 (1.15–2.17)	37.9		
Both	1.35 (1.09–1.67)	86.1		
Steenland et al. (13)				
Men	1.10 (0.82–1.31)	123.1	—	—
Women	1.09 (0.78–1.52)	34.5	—	—

	Morbidity+Mortality		Morbidity		Mortality	
	Adjusted OR or RR (95% CI)	Statistical Weight	Adjusted OR or RR (95% CI)	Statistical Weight	Adjusted OR or RR (95% CI)	Statistical Weight
Total						
Men	1.13 (0.97–1.31)	171.3	1.28 (0.91–1.79)	33.6	1.09 (0.92–1.29)	137.7
Women	1.32 (1.05–1.66)	72.4	1.38 (0.91–2.10)	21.9	1.29 (0.98–1.70)	50.5
Both	1.18 (1.04–1.34)	235.6	1.32 (1.01–1.72)	55.5	1.14 (0.99–1.32)	188.2

*Six to 10, 11 to 20, 20+ cigarettes/day smoked by co-workers (p = 0.022 for trend). †Six to 15, 16+ years of exposure (p = 0.12 for trend). ‡One to two, three, four or more smokers (p = 0.024 for trend). §One to 2, 3 to 4, 5+ h/day of exposure (p = 0.002 for trend). ‖Occasional, regular exposure. ¶One to 10, 11+ years of exposure. CI = confidence interval; OR = odds ratio; ref = reference; RR = relative risk; — = no data.

used only a checkmark. No analysis of intensity of exposure at work is given. The workplace RR chosen here is for workers <65 years old because most of the workers >65 years old would have retired during the 7-year follow-up period and would no longer have been exposed to ETS at work. Although very large, and therefore having high statistical weight, and having adjusted for a number of heart disease risk factors, the American Cancer Society study, as a workplace study, leaves much to be desired in terms of the quality of its exposure data. No formal tier level was assigned to this study.

The combined RR for the studies by He et al. (9) and Kawachi et al. (10), probably the two best studies, is 1.76 (95% CI 1.04 to 2.98). Inclusion of the results from Butler (18) reduces the combined RR for both men and women to 1.50 (95% CI 1.12 to 2.01). Adding the other four studies (except Steenland et al. [13]) approximately doubles the statistical weight from 44.4 to 86.1 but reduces the combined RR to 1.35 (95% CI 1.09 to 1.67). Inclusion of the study by Steenland et al. (13), with its total weight of 157.6 and questionable exposure history, nearly triples the statistical weight but reduces the combined RR to 1.18 (95% CI 1.04 to 1.34).

With regard to dose response only, He et al. (9) and Butler (18) provide data for duration of exposure, and there is no evidence that longer exposure is associated with a higher risk than shorter exposure. For intensity of exposure, we have data from both He et al. (9) and Kawachi et al. (10). Here, a strong effect of higher risk with higher dose is observed. The morbidity and mortality RR values (Table 2) are higher for women than for men. The morbidity RR values for workplace exposure are higher than those for mortality, which is consistent

with the largely home-based results (see Appendix, Tables A2 and A3).

Discussion

As noted, the quality of some of the workplace studies is marginal at best. Recall bias may not be a serious problem because no surrogate responders were used, except for some of the fatal cases in Dobson et al. (21). Trained interviewers were used for most of the studies, although Kawachi et al. (10) relied on mailed questionnaires, and, as noted, Steenland et al. (13) used American Chemical Society volunteers. Repeatability of workplace exposure estimates has been investigated by Pron et al. (22) indicating that repeatability for female never-smokers is about the same for occupational and residential exposure, but the comparison is less good for men, which may be reflected in the lower combined workplace RR for men than for women. Alternatively, their lower RR may be due to chance because in the largely home-based exposure RRs in the Appendix, the gender results are mixed. Not all the studies adjusted for the same heart risk factors, but where crude and adjusted RRs were given, they were not radically different. Also, the adjustments tended to offset each other in the combined RRs because adjustments in some of the studies increased RRs, whereas in others they were reduced.

Taking all seven studies together, there is evidence that exposure to ETS at the workplace is associated with heart disease and that the combined RRs are statistically significant. The combined RRs for studies with the better workplace exposure histories (9,10,18) are similar to the combined RRs from the better studies of total residential exposure, as shown in the Appendix (Tables A2 and A3). This similarity is supported by the observation in the 1992 Environmental Protection Agency (EPA) report (23) that, on the basis of ambient nicotine measurements, workplace and residential exposures to ETS are similar. It is also evident that the studies with better workplace ETS exposure histories (9,10,18) have higher RRs than those with poorer histories (12,13,15,20,21). Thus, the workplace data relating passive smoking to heart disease support the studies based on home-based exposure and indicate that using the home-based RRs to predict workplace effects is probably valid.

Appendix

Update of the 1994 Review of Heart Disease From Exposure at Home to Environmental Tobacco Smoke

Seven studies of passive smoking and heart disease (8–14) that have recently appeared were not included in the 1994 review (1) on that subject. Brief descriptions of the new studies, similar to those in Table 1 of Wells (1), are presented in Table A1. As before, the studies are assigned to quality tier levels on the basis of the numbers of other heart disease risk factors for which the investigators made adjustments. The study by He et al. (9) emphasizes workplace exposure but also includes data on spousal exposure and combined exposure from spouse and at work. The study by Tunstall-Pedoe et al. (14) reports an association between heart disease and exposure to "tobacco smoke from someone else in the last three days." They report exposure on the basis of self-report and serum cotinine levels, both for diagnosed and undiagnosed coronary heart disease (CHD). I chose the odds ratio based on serum cotinine data for diagnosed CHD as the most relevant. The large study by Steenland et al. (13) is much better for spousal exposure than for workplace exposure because they had matching data on spousal smoking habits provided by the spouses themselves, which gives a measure of duration of exposure that was absent from the workplace data. Steenland et al. (13) found very little risk for exposure to ex-smoker compared with current-smoker spouses. For the present analysis I chose their relative risks (RRs) where both spouses confirmed each other's smoking status because these data would be least

Table A1. Recent Studies of Passive Smoking and Ischemic Heart Disease Among Never-Smokers Not Included in 1994 Review*

Study (ref no.)	Locale	Time Frame	Study Type	No. of Cases		Population or Control Subjects		End Point	Fatal or Nonfatal	Adjustment Factors	Quality Tier Assigned†
				F	M	F	M				
Ciruzzi et al. (8)	Argentina	1991–1994	C/C	336		446		AMI	nf	A, B, C, D, E, FIHD, SX, W	1
He et al. (9)‡	China	1989–1992	C/C	59	—	126	—	CHD	nf	See Table 1	1
Kawachi et al. (10)	USA	1982–1992	Pros	25	—	32,046	—	CHD	f	See Table 1	1
				152	—	32,046	—	CHD	nf	See Table 1	1
La Vecchia et al. (11)	Italy	1988–1989	C/C	44	69	60	125	AMI	nf	A, B, C, CF, D, E, FIHD, SX, W	1
Muscat and Wynder (12)	USA	1980–1990	C/C	46	68	50	108	MI	nf	See Table 1	3
Steenland et al. (13)	USA	1982–1989	Pros	426	1,180	80,549	54,668	CHD	f	See Table 1	1
Tunstall-Pedoe et al. (14)	Scotland	1984–1986	CS	70		2,278		CHD	nf	A, B, C, HT	3

*Wells (1). †Tier 1 studies were adjusted for six of the following or five plus two others: age, hypertension, cholesterol, weight, social class, marital status, personal history of heart disease, exercise and history of diabetes; tier 2 studies for four of the above or three plus two others; tier 3 studies for two of the above or one plus two others; tier 4 studies for fewer than tier 3. ‡Replaces earlier report, which was reference 31 in Wells (1). A = age; AMI = acute myocardial infarction; B = blood pressure or hypertension; C = cholesterol; C/C = case control; CHD = coronary heart disease; CS = cross sectional; D = diabetes; E = education; f = fatal; F = female; FIHD = family history of heart disease; HT = housing tenure; M = male; MI = myocardial infarction; nf = nonfatal; Pros = prospective; ref = reference; SX = gender; — = not applicable.

Table A2. Studies Associating Ischemic Heart Disease Morbidity With Passive Smoking

Study (ref no.)	Exposure: All Adult Adjusted OR or RR (95% CI)	All Adult Statistical Weight	Home Only Adjusted OR or RR (95% CI)	Home Only Statistical Weight	Spouse Only Adjusted OR or RR (95% CI)	Spouse Only Statistical Weight	Dose Response: Intensity	Dose Response: Duration	Quality Tier
Ciruzzi et al. (8)									
M+F	—		1.66 (1.2–2.3)	36.3	1.43 (0.9–2.3)*	17.5	1.27, 2.41†	—	1
He et al. (24)									
F	—		—		1.50 (0.63–3.6)	5.1	—	—	1
He et al. (9)									
F	2.36 (1.01–5.55)	5.3	—		1.24 (0.56–2.72)	6.2	1.75, 3.11, 7.61‡	—	1
Kawachi et al. (10)§									
F	1.71 (1.03–2.84)	14.9	1.53 (0.81–2.90)	9.4	—		1.19, 2.11‖	0.91, 1.54, 1.11, 1.50¶	1
La Vecchia et al. (11)									
M+F	—		—		1.08 (0.58–2.01)	9.9	0.91, 1.21# 1.13, 1.30**	—	1
Svendsen et al. (20)§									
M	—		—		1.61 (0.96–2.71)	14.3	1.2, 1.75††	—	1
Hole et al. (25)									
M+F	—		1.13 (0.77–1.66)	25.6	—		1.3, 1.6‡‡	—	2
Dobson et al. (21)§									
M	—		0.97 (0.50–1.86)	8.9	—		—	—	3
F	—		2.46 (1.47–4.13)	14.4	—		—	—	3
Jackson (15)									
M	2.7 (0.6–12.1)	1.7	1.03 (0.27–3.9)	2.2	—		—	—	3
F	4.4 (0.4–49.5)	0.7	2.7 (0.57–12.3)	1.6	—		—	—	3
Lee et al. (26)									
M	—		—		1.24 (0.59–2.59)	7.1	—	—	3
F	—		—		0.93 (0.54–1.62)	12.6	—	—	3
Muscat and Wynder (12)§§									
M+F	1.5 (0.9–2.6)	13.7		—		—	—	No trend	3
Tunstall-Pedoe et al. (14)									
M+F	1.9 (1.1–3.3)	11.9	—		—		1.5, 1.7, 2.7‖ ‖		3
M, combined	2.7 (0.6–12.1)	1.7	0.98 (0.54–1.76)	11.1	1.47 (0.96–2.25)	21.4			
F, combined	1.92 (1.25–2.95)	20.9	2.08 (1.41–3.07)	25.4	1.11 (0.74–1.66)	23.4			
M+F	1.80 (1.36–2.39)	48.2	1.50 (1.23–1.83)	98.4	1.28 (1.02–1.61)	72.7			
M+F, tier 1 only	1.86 (1.20–2.88)	20.2	1.63 (1.22–2.18)	45.7	1.39 (1.06–1.82)	53.0			
M+F, all studies, broadest exposure for each	1.49 (1.29–1.78)	182.4							

*Upper confidence limit increased by the present author from 2, as published in Ciruzzi et al. (3), to 2.3 to be consistent with lower confidence limit and point estimate in the report. †One to 20, 20+ cigarettes/day by spouse. ‡Low, moderate, high total exposure (cigarettes/day × years). ‖Occasional, regular exposure at home. §Includes some fatal cases (see Table 1, present report, or Table 1, Wells [1]). ¶One to 9, 10 to 19, 20 to 29, 30+ years of home exposure. #Ex-smoker, current smoker. **Less than 15, 15+ cigarettes/day. ††One to 19, 20+ cigarettes/day. ‡‡Less than 15, 15+ cigarettes/day (females only). §§Separate adjusted odds ratios (OR) for males (M) and females (F) can be estimated by combining ORs for each of three levels of exposure duration and are 1.4 for males and 1.5 for females; there is no evidence of trend for longer versus shorter exposure. ‖ ‖Little, some, a lot of exposure (cotinine groups). CI = confidence interval; ref = reference; RR = relative risk; — = no data.

subject to exposure misclassification (Steenland et al. [13], Table 5). Although this data set provides RRs for exposure to currently smoking spouses only, it should cover most of the passive smoking effects.

Tables 2 and 3 from the 1994 review (1) covered morbidity and mortality RRs, respectively, for passive smoking and heart disease. They have been revised to include the new studies and are shown as Tables A2 and A3. The revised tables classify exposure into all-adult, total home and spouse-only exposure. This classification was done to show that, as many suspect, spousal exposure is a weak measure for determining passive smoking effect, probably because of the large background effects of environmental tobacco smoke (ETS) in Western developed countries. Except for the effects of the result of Dobson et al. (21) on the combined male morbidity RR for home exposure and the result of Jackson (15) on the combined male mortality RR for all exposures, the RRs for both the individual studies and the combinations shown in Tables A2 and A3 increase as the breadth of exposure expands from spouse only to total home to all exposures. If one uses the OR or RR for the broadest exposure available for each study, the combined male plus female RR for all studies is 1.49 (95% CI 1.29 to 1.72) for morbidity and 1.23 (95% CI 1.14 to 1.32) for mortality. For

Table A3. Studies Associating Ischemic Heart Disease Mortality With Passive Smoking

	Exposure						Response		
	All Adult		Home Only		Spouse Only		Dose		
Study (ref no.)	Adjusted OR or RR (95% CI)	Statistical Weight	Adjusted OR or RR (95% CI)	Statistical Weight	Adjusted OR or RR (95% CI)	Statistical Weight	Intensity	Duration	Quality Tier
Garland et al. (27)									
F	—		—		2.7 (0.7–10.5)	2.1	3.0, 2.25*	—	1
Kawachi et al. (10)									
F	1.87 (0.56–6.20)	2.1	—		—		1.50, 2.55†	—	1
Steenland et al. (13)‡									
M	—		—		1.23 (1.03–1.47)	121.5	1.37, 1.15, 1.12§	1.14, 1.13, 1.14, 1.25‖	1
F	—		—		1.19 (0.97–1.45)	95.1	1.22, 1.14, 1.02, 1.28¶	0.84, 0.99, 1.20, 1.20‖	1
Svendsen et al. (20)									
M	—		—		2.23 (0.72–6.92)	3.0	0.90, 3.21#		1
Hole et al. (25)									
M	—		1.73 (1.01–2.96)	13.3**	—				2
F	—		1.65 (0.79–3.46)	7.0**	—		2.09, 4.12††		2
Humble et al. (28)‡									
F	—		—		1.59 (0.99–2.57)	16.9	1.02, 2.11, 2.55‡‡§§	p = 0.09 for trend§§	2
Jackson (15)									
M	1.1 (0.23–5.2)	1.6	0.6 (0.06–5.9)	0.7	—				3
F	5.8 (0.95–35.2)	1.2	23.5 (2.8–199)	0.8	—				3
Sandler et al. (29)									
M	—		1.31 (1.05–1.64)	77.3	—		1.38, 1.25‖‖		3
F	—		1.19 (1.04–1.36)	213.5	—		1.20, 1.27‖‖		3
Butler (18)¶¶									
M	—		—		0.55 (0.29–1.04)	9.6	—	0.41, 0.61†††	4
F	—		—		1.28 (0.90–1.81)##	31.9##	—	1.46, 1.53†††	4
Hirayama (30)									
F	—		—		1.15 (0.93–1.42)	85.8	1.08, 1.30‡‡‡		4
M, combined	1.1 (0.23–5.2)	1.6	1.36 (1.10–1.66)	91.3	1.18 (1.00–1.40)	134.3			
F, combined	2.82 (0.95–8.3)	3.3	1.22 (1.07–1.39)	221.3	1.22 (1.07–1.40)	208.8			
M+F	2.08 (0.86–5.03)	4.9	1.25 (1.12–1.40)	312.6	1.21 (1.09–1.35)	342.9			
M+F, tier 1 only	1.87 (0.56–6.20)	2.1	—		1.23 (1.08–1.40)	221.7			
M+F, all studies, broadest exposure for each	1.23 (1.14–1.32)	681.9							

*Ex-smokers, current smokers. †Occasional, regular exposure. ‡Exposure to currently smoking spouses only. §Cigarettes/day: <20, 20, >20. ‖For males (M): 1–12, 13–21, 22–29, 30+ years; for females (F): 1–14, 15–25, 26–33, 34+ years. ¶Cigarettes/day: <20, 20, 21–39, 40+. #Cigarettes/day: 1–19, 20+. **Relative risk (RR) values updated through 1988 by Hole DJ, personal communication, January 1990. ††Cigarettes/day: <15, 15+. ‡‡Cigarettes/day: <10, 10–20, >20. §§For high social status whites only. ‖‖Cigarettes/day: <10, 10+; from related paper, Helsing et al. (31): Cigarettes/day approximated on the basis of exposure scores. ¶¶Exposure from a few nonspouse household members but mostly from spouses. ##For female subjects, Butler (18) provided data for two partly overlapping cohorts: 11,660 spouse pairs (80 deaths) and 4,122 female subjects from the Adventist Health Smog Study (AHSMOG) (70 deaths). The values shown are estimated for a combination of the spouse pairs and AHSMOG cohorts. The data for male subjects are from the AHSMOG cohort only. †††One to 10, 11+ years. ###Cigarettes/day: ex-smoker plus 1–19, 20+. Other abbreviations as in Table A2.

morbidity and mortality combined, the RR is 1.28 (95% CI 1.20 to 1.37).

The classification scheme used has five of the seven new studies (8–11,13) as tier 1 in quality, meaning that they adjusted for a large number of heart risk factors. Also, five of the seven studies report RRs ≥1.5, increasing the confidence that the observed effect is real and not the effect of some as yet undiscovered source of confounding. Two studies related to the tobacco industry have not been included. The analysis of the American Cancer Society data by LeVois and Layard (32) was rejected as vague as to which subjects were included and which excluded. It has been superceded by the more detailed analysis by Steenland et al. (13) of much of the same data set. Also rejected was the study by Layard (33) of a 1% sample of U.S. deaths from the 1986 National Mortality Followback Survey (NMFS). The sample was heavily overweighted in blacks, Native Americans, young persons and young persons who had died of ischemic heart disease (34). A mailed questionnaire was used. Because the subjects were already dead, their smoking status and lifestyle characteristics were determined 100% by surrogates. ETS exposure was from spouses only, and 65% of their smoking status was determined by surrogates, in contrast to the larger

mortality studies in Table A3, where the smoking status of the subjects, their spouses and other household members all came from direct interviews. The ETS exposure in Layard (33) was from any spouse who smoked >100 cigarettes in total at anytime during the various marriages, so that it would have included exposure from ex-smokers who had quit a long time ago or current smokers, some of whom would have been occasional or light smokers. With the high proportion of surrogate responses, there is often confusion between those subjects who are reported as unexposed and those who are reported as lightly exposed. In the light of all these difficulties, it was decided to reject the study by Layard (33).

Neither LeVois and Layard (32) or Layard (33) found any association between passive smoking and heart disease. However, if one assumes that there might have been confusion between the reported lightly exposed subjects in the study by Layard (33) and the reported unexposed subjects, and if the two groups had been lumped together as a combined reference category, the OR for the more heavily exposed subjects would have been raised to about the 1.15 level. Even if the results of Layard had been included as is, the combined RR for broadest exposure for mortality would have been reduced from the 1.23 RR noted above to 1.17 (95% CI 1.10 to 1.25) and for mortality and morbidity combined, from 1.28 to 1.22 (95% CI 1.15 to 1.29).

In the 1994 review (1) probable deaths from passive smoking and heart disease were calculated on the basis of the combined RR for men plus women for those U.S. studies that were classed as tier 3 or better. The combined RR was 1.25 (95% CI 1.12 to 1.40) before correction for smoker misclassification and 1.22 after such correction. The "home only" or "spouse only" columns in Table A3 are probably the closest to the exposure that was used in 1994. They now include the studies by Kawachi et al. (10) and Steenland et al. (13) and some correction to the statistical weights of Butler et al. (18). The combined male plus female RR for the U.S. studies classified as tier 3 or better is still 1.25 (95% CI 1.15 to 1.36), the same as before but with a slightly tighter CI. Therefore, the death estimates from the 1994 review (1) remain essentially unchanged.

With respect to dose response, many of the studies show increases in heart disease risk with increasing intensity of exposure, but the data on duration of exposure are not consistent with respect to trend. Most of the studies show increased risks relative to no exposure, but the risks from longer exposure are not consistently higher than the risks from shorter exposure. Only the data of Steenland et al. (13) show a weak positive trend with increased duration of exposure for both men and women. Also, most of the studies that provide data on exposure to ex-smokers as well as current smokers indicate that exposure to current smokers results in higher risks. Overall, these results are consistent with the concept (6) that heart disease risks from cigarette smoke are a combination of short- and long-term effects.

The biologic plausibility of heart disease from passive smoking has been dealt with at length by Glantz and Parmley (3,6) in their reviews and in their recent editorial (7). In brief, acute exposure to ETS has a negative short-term effect on the ability of the heart to receive and process oxygen; it activates platelets in the blood, causing them to become stickier; and it enhances their ability to damage the lining of the coronary arteries. Longer term effects from chronic exposure include the acceleration of plaque formation in the arteries. The new epidemiologic evidence for an association of increased heart disease risk with ETS exposure reinforces what was available in 1994 and is consistent with the biologic evidence that ETS has short-term as well as long-term adverse effects on the cardiovascular system. This in turn suggests that the effect is causal.

References

1. Wells AJ. Passive smoking as a cause of heart disease. J Am Coll Cardiol 1994;24:546–54.
2. Wells AJ. An estimate of adult mortality in the United States from passive smoking. Environment International 1988;14:249–65.
3. Glantz SA, Parmley WW. Passive smoking and heart disease; epidemiology, physiology, and biochemistry. Circulation 1991;83:1–12.
4. Steenland K. Passive smoking and risk of heart disease. JAMA 1992;267: 94–9.
5. Taylor AE, Johnson DC, Kazemi H. Environmental tobacco smoke and cardiovascular disease; a position paper from the Council on Cardiopulmonary Care, American Heart Association. Circulation 1992;86:699–702.
6. Glantz SA, Parmley WW. Passive smoking and heart disease; mechanisms and risk. JAMA 1995;273:1047–53.
7. Glantz SA, Parmley WW. Passive and active smoking; a problem for adults. Circulation 1996;94:596–8.
8. Ciruzzi M, Esteban O, Rozlosnik J, et al. Passive smoking and the risk of acute myocardial infarction [abstract]. Eur Heart J 1996;17 Suppl:309.
9. He Y, Lam TH, Li LS, et al. Passive smoking at work as a risk factor for coronary heart disease in Chinese women who have never smoked. BMJ 1994;308:380–4.
10. Kawachi I, Colditz GA, Speizer FE, et al. A prospective study of passive smoking and coronary heart disease. Circulation 1997;95:2374–9.
11. La Vecchia C, D'Avanzo B, Franzosi MG, Tognoni G. Passive smoking and the risk of acute myocardial infarction [letter]. Lancet 1993;341:505–6.
12. Muscat JE, Wynder EL. Exposure to environmental tobacco smoke and the risk of heart attack. Int J Epidemiol 1995;24:715–9.
13. Steenland K, Thun M, Lally C, Heath C Jr. Environmental tobacco smoke and coronary heart disease in the American Cancer Society CPS-II cohort. Circulation 1996;94:622–8.
14. Tunstall-Pedoe H, Brown CA, Woodward M, Tavendale R. Passive smoking by self report and serum cotinine and the prevalence of respiratory and coronary heart disease in the Scottish heart health study. J Epidemiol Community Health 1995;49:139–43.
15. Jackson RT. The Auckland heart study [dissertation]. Auckland, New Zealand: Univ of Auckland, 1989;157–172.
16. Breslau NE, Day NE. Statistical Methods in Cancer Research, vol. 1: The Analysis of Case-Control Studies. Lyon, France: International Agency for Research on Cancer, 1980:69–73.
17. Rothman KJ. Modern Epidemiology. Boston: Little, Brown, 1986:146, 344.
18. Butler TL. The relationship of passive smoking to various health outcomes among Seventh Day Adventists in California [dissertation]. Los Angeles (CA): Univ of California, 1988:160–179.
19. Morabia A, Bernstein M, Heritier S, Khatchatrian. Relation of breast cancer with passive and active exposure to tobacco smoke. Am J Epidemiol 1996;143:918–28.
20. Svendsen KH, Kuller LH, Martin MJ, Ockene JK. Effects of passive smoking in the Multiple Risk Factor Intervention trial. Am J Epidemiol 1987;126: 783–95.
21. Dobson AJ, Alexander HM, Heller RF, Lloyd DM. Passive smoking and the risk of heart attack or coronary death. Med J Aust 1991;154:793–7.
22. Pron GE, Burch JD, Howe GR, Miller AB. The reliability of passive smoking histories reported in a case-control study of lung cancer. Am J Epidemiol 1988;127:267–73.
23. Respiratory health effects of passive smoking: lung cancer and other disorders; a report of the U.S. Environmental Protection Agency. Washington (DC): National Institutes of Health, NIH Publication No. 93-3605, 1993:59.
24. He Y, Lam TH, Wan Z, et al. Women's passive smoking and coronary heart disease. Chin J Prev Med 1989;23:19–22.
25. Hole DJ, Gillis CR, Chopra C, Hawthorne VM. Passive smoking and cardiorespiratory health in a general population in the west of Scotland. BMJ 1989;299:423–7.
26. Lee PN, Chamberlain J, Alderson MR. Relationship of passive smoking to risk of lung cancer and other smoking related diseases. Br J Cancer 1986;54:97–105.
27. Garland C, Barrett-Connor E, Suarez L, Criqui MH, Wingard DL. Effects of passive smoking on ischemic heart disease mortality of nonsmokers. Am J Epidemiol 1985;121:645–50.

28. Humble C, Croft J, Gerber A, Casper M, Hames CG, Tyroler HA. Passive smoking and 20-year cardiovascular disease mortality among nonsmoking wives, Evans County, Georgia. Am J Public Health 1990;80:599–601.
29. Sandler DP, Comstock GW, Helsing KJ, Shore DL. Deaths from all causes in nonsmokers who lived with smokers. Am J Public Health 1989;79:163–7.
30. Hirayama T. Passive smoking. N Z Med J 1990;103:54.
31. Helsing KJ, Sandler DP, Comstock GW, Chee E. Heart disease mortality in nonsmokers living with smokers. Am J Epidemiol 1988;127:915–22.
32. LeVois ME, Layard MW. Publication bias in the environmental tobacco smoke/coronary heart disease epidemiologic literature. Regul Toxicol Pharmacol 1995;21:184–91.
33. Layard MW. Ischemic heart disease and spousal smoking in the National Mortality Followback Survey. Regul Toxicol Pharmacol 1995;21:180–3.
34. Seeman I, Poe GS, McLaughlin JK. Design of the 1986 National Mortality Followback Survey: considerations on collecting data on decedents. Public Health Rep 1989;104:183–8.