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Changes in Environmental Tobacco Smoke Exposure: The Beaver Dam Experience

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Abstract

Objectives—Environmental tobacco smoke (ETS) exposure has been associated with adverse health outcomes. Our goal was to determine if ETS exposure changed between 1998–2000 and 2003–2005 among participants in the population-based Epidemiology of Hearing Loss Study.

Methods—ETS exposure was ascertained using a cotinine-validated questionnaire at the 5-year (1998–2000) and 10-year follow-up examinations (2003–2005). Non-smoking participants with data from both visits were included (n=1898; ages 53–96 years at 5-yr follow-up). McNemar's test was used to test differences in ETS exposure overall and in three settings: home, work, and social settings. Generalized estimating equations (GEE) were used for multivariate logistic regression models of exposure.

Results—The proportion of nonsmokers with no or little ETS exposure increased from 80% to 88% (p<0.0001). The percent living in a home with no indoor smokers increased from 94% to 97% (p<0.0001). The percent reporting no exposure at work increased from 91% to 95% (p<0.0001). The percent reporting the lowest frequency of social exposure increased from 65% to 77% (p<0.0001). In the GEE model, age was inversely associated with exposure (Odds Ratio (OR) per 5 yr=0.80, 95% Confidence Interval (95% CI)=0.76, 0.86), as was education (OR for college vs <high school=0.25, 95% CI=0.16,0.37), female gender (OR=0.39, 95% CI=0.31,0.48) and later examination period (OR=0.61, 95% CI=0.52,0.72).

Conclusions—Between the late 1990s and the mid-2000s, ETS exposure in older adults decreased. Decreasing exposures suggest there may be future declines in ETS-related adverse health outcomes.

Introduction

Exposure to environmental tobacco smoke (ETS) has been associated with adverse health outcomes in nonsmokers. In 1992, the Environmental Protection Agency (EPA) classified

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ETS as a known human carcinogen.[1] The effects on the cardiovascular system are estimated to be substantial, on average 80–90% as large as that from active smoking (averaged across mechanistic effects, e.g., endothelial dysfunction, arterial stiffness).[2] ETS exposure occurs in a variety of settings, including home, work, and social settings. Exposure in the home and workplace may be particularly harmful, as many people spend much of their time at home and in their workplaces. ETS exposure in the workplace was previously estimated to result in about 1710 excess ischemic heart disease deaths per year among 35–69 year old nonsmoking U.S. workers.[3] A meta-analysis of 17 studies estimated a relative risk for coronary events of 1.25 (95% CI = 1.17–1.33) among never smoking spouses married to smokers, compared to those with nonsmoking spouses.[4] In recent decades, increasing awareness of the harms of ETS has led to attempts to reduce or avoid exposure, and some cross-sectional population-based studies have reported declining temporal trends, as did one longitudinal study which excluded women.[5–8]

We aimed to determine if ETS exposure changed among non-smoking older adult participants in a longitudinal population-based study during the five-year period between two examinations: 1998–2000 and 2003–2005. In particular, we investigated whether later time period was associated with ETS exposure in a variety of settings, after taking into account important temporal changes including age of the participants, retirement, and spousal death.

Methods

Study population

The Epidemiology of Hearing Loss Study (EHLS) is a population-based longitudinal study of sensory loss and aging in Beaver Dam, WI (1993-present). A private census was conducted in 1987–1988 which identified 43 to 84 year old residents of the city or township of Beaver Dam, WI (n=5924). In 1988–1990, 4926 of the 5925 eligible (83%) participated in the first examination phase of the Beaver Dam Eye Study (BDES).[9] Those who participated in the baseline BDES and were alive on March 1, 1993 (n=4541) were eligible for the EHLS, and 3753 (82.6%) participated in the baseline EHLS examination phase from 1993–1995.[10] The EHLS five-year follow-up examinations took place from 1998–2000 and, of the 3407 EHLS participants alive as of March 1998, 2800 (82.2%) participated.[11] During the 10-year follow-up examination phase in 2003–2005, 2395 (82.5% of survivors) participated.[12]

Participants who provided ETS questionnaire data at both the 5-year (1998–2000) and the 10-year (2003–2005) follow-up interviews were included in this study (n=2231). Analyses were limited to participants who were nonsmokers at both time points (n=1898), 87.1% and 89% of all participants at the 5- and 10-year follow-up examinations, respectively. This study was approved by the Health Sciences Institutional Review Board of the University of Wisconsin and informed consent was obtained from each participant.

Data collection

At both time points, participants provided information on ETS exposure in three settings: home, work, and social activities. Those not working were coded as having no workplace exposure. Cotinine data on a subset of the cohort (n=643) from the five-year follow-up examinations were previously used to develop a three-level cotinine-validated ETS exposure scale that uses only the self-reported questionnaire data, allowing estimation of ETS exposure among the entire cohort.[13] The scale conveniently categorizes overall ETS exposure, combining information about work, home, and social ETS exposure, utilizing one questionnaire item from each type of setting: the number of hours per day exposed to ETS at

work (none, < 1h/day, 1–4h/day, or >4h/day), exposure at home (number of housemates who smoke in the home), and the frequency of exposure in social settings (seldom, once a week, several times a week, or daily). Participants were considered to have high ETS exposure if they (1) had >4h/day of exposure at work, (2) were living with a person who smokes in their home, or (3) were exposed daily to ETS in social settings outside the home. Participants not fitting those criteria were categorized as having moderate exposure if they had 1–4h/day of workplace exposure or social ETS exposure several times a week. Finally, participants not categorized as having high or moderate exposure were considered to have little or no ETS exposure.

Because small numbers of participants reported higher ETS exposure levels, the greater categories of exposure were combined into one category (exposed) and compared to the lowest category (little or no exposure) as follows: for overall ETS exposure, ‘moderate’ and ‘high’ vs. ‘no/little’; for exposure in social settings, ≥once/week vs. seldom; for home exposure, ≥1 smoker in home vs. no smokers; for work exposure, any time exposed at work vs. never exposed.

Statistical analyses

Statistical analyses were conducted using SAS software (version 9.2; SAS Institute, Inc., Cary, NC). McNemar’s test was used to test for change between the two time points in ETS exposure (lowest category vs. higher categories), overall and in each setting. Generalized estimating equations (GEE) logistic regression was used to investigate factors associated with ETS exposure, overall and in each of the three specific settings. The GEE models were generated with the GENMOD procedure, using the REPEATED statement and specifying “unstructured” as the working correlation matrix to account for the correlation of responses from the same participants at two time points.

Models for each specific setting and overall ETS exposure included age, sex, education, and time period (2003–2005 vs. 1998–2000). Additional factors which would be likely to influence ETS exposure (i.e., number of other people living in the home, employment status and change in employment status, change in marital status, etc.) were considered as potential confounders. Workplace exposure models were restricted to those working at both time points (n=350). The main independent variable of interest in all models was time period, to determine whether exposure was decreasing in this community over the 5-year period, other than through major age-related life changes such as retirement or death of a spouse.

Results

This sample of nonsmokers was 61% female. Fifty percent had a high school education and 35% had more than a high school education. During the period between the 5-year and 10-year follow-ups, the portion employed decreased from 39% to 27% and the portion widowed increased from 20% to 26% (Table 1).

Between the 5- and 10-year follow-up examination phases the proportion with decreased ETS exposure was significantly greater than the proportion with increased ETS exposure, overall and in each specific setting ($p < .0001$ for each). For overall ETS exposure, participants were more likely to be classified as having “no/little ETS” at the 10-year follow-up (88%) than at the 5-year follow-up examination (80%) (Figure 1). By specific setting, during the 5- and 10-year follow-up examinations, 65% and 77%, respectively, reported “seldom” being exposed to tobacco smoke in social settings outside their own home; 91% and 95%, respectively, reported no workplace ETS exposure; 94% and 97%, respectively, lived in a home with no indoor smokers (Figure 1). Among the 116 participants whose workplace exposure decreased to none, 61 had retired, 14 had changed from full-time

to part-time employment, and 1 became unemployed/disabled. Of the 69 participants whose home ETS exposure decreased to none, 11 were widowed and 2 divorced during the interval.

To determine whether retirement or transitions to part-time employment were driving the decrease in workplace ETS exposure, we examined exposure change among the 356 participants who were working full-time at both points or part-time at both points (i.e., those who changed from full-time to part-time or vice versa, or were not working at either or both points, were excluded). Among this subset, 78% reported no exposure at the 5-year follow-up, compared to 80% at the 10-year ($p = 0.47$). Similarly, ETS exposure in the home was investigated amongst the subset with no change in marital status (n= 1620) and found 94% with no exposure at the 5-year follow-up and 97% with no home exposure at the 10-year follow-up ($p < .0001$). Among the subset who lived with at least one other person at both time points (n=1255), the difference was slightly less (93% vs. 95% with no exposure; $p < .0001$).

In a multivariate GEE model, factors associated with lower odds for overall ETS exposure were greater age, female sex, more education, and later time period (2003–2005 vs. 1998–2000) (Table 2). Current employment was associated with increased odds of overall ETS exposure. For ETS in social settings, the same factors were associated with lower odds of exposure, except current employment, which was not part of the model. Fewer factors were associated with lower odds of ETS exposure at home, including later time period, and having a college education (vs. less than high school). Not surprisingly, the odds of exposure in the home were also increased with each additional person living in the home (OR = 1.5 for each person). The analysis of ETS exposure in the workplace was limited to those participants who were employed at both time points. Greater age, female sex, and a college education (vs. less than high school), were associated with lower odds of exposure at work. Time period was not significantly associated with workplace exposure.

Discussion

Over a 5-year period, ETS exposure declined in this population of older adults. Decreases in exposure were observed for all settings examined (home, work, and social settings). Controlling for several factors including age, later time period was associated with reduced odds of exposure at home and in social settings, but was not significantly associated with odds of exposure at work, although temporal shifts in workplace ETS exposure may have occurred prior to 1998 as some employers instituted smoke-free policies. Older age and female sex were each associated with decreased odds of exposure at work and in social settings, but not associated with home exposure. College education, compared to less than high school education, was associated with reduced odds of exposure in all three settings.

In this cohort of older participants, we expected retirement and death among smoking spouses would explain some of the decreased ETS exposure. Among those working at both time points, the percentage reporting no workplace exposure was similar, but slightly greater at the later time period (78% vs. 80% at the earlier time period) and later time period was not associated with reduced odds of exposure at work in the multivariate GEE model. Thus, among this older population, retirement and reduced work hours appear to account for a portion of the small decrease in prevalence of workplace exposure that was found in the whole sample. Regarding exposure in the home, we observed the same decrease as in the whole sample when we looked at the subset with no change in marital status, suggesting that death of smoking spouses was not a major reason for the small decrease noted in the prevalence of ETS exposure at home.

These results are consistent with reports of decreased ETS exposure among nonsmokers in the U.S. population, based on several analyses using National Health and Nutrition Examination Survey (NHANES) cotinine data.[7–8] Pirkle et al. reported that serum cotinine levels in nonsmokers decreased by 70% between 1988 and 2002.[8] Chen et al. analyzed NHANES cotinine data collected from 2001 – 2006 and concluded that the previously observed declining trend in ETS exposure has leveled off.[7] A Centers for Disease Control report stated the prevalence among nonsmokers of serum cotinine levels ≥ 0.05 ng/mL decreased from 52.5% in 1999–2000 to 40.1% in 2007–2008, and that the greatest change was observed between the periods 1999–2000 and 2001–2002.[14] The current study included this time period in which greatest change was observed in the NHANES data.

In general, reductions in ETS exposure are thought to be due to decreases in the prevalence of smoking, implementation of non-smoking policies and laws for workplaces and public indoor spaces, individual household bans on indoor smoking, and a general shift in social norms towards the unacceptability of exposing nonsmokers, especially children or frail individuals, to ETS.[15] In the present study, the decreased odds of exposure at the later time period, independent of age and other covariates, likely reflects such changes in cultural norms in this population from south central Wisconsin, although we had no data to test this directly. It is likely that ETS exposure levels, especially in public places and workplaces, have decreased after this period due to a Wisconsin statewide ban on smoking in enclosed public places and workplaces, which took effect on July 5, 2010. Supporting this possibility, a recent study from the Survey of the Health of Wisconsin reported that participants interviewed after July 5, 2010 were less likely to report ETS exposure and more likely to report smoking bans in their households, compared to those interviewed before July 5, 2010.[16] In particular, they observed greater differences among older participants, for both home and work ETS, suggesting that policy changes may have led to subsequent reductions in ETS exposure among older Wisconsin adults. Our longitudinal data, with repeated assessments in the same people, are consistent with their findings.

Interpretation of the current results should take into account some strengths and limitations of the study. A potential limitation is that exposure data was self-reported. Cotinine measures would have provided an objective measure. However, previous analyses comparing self-reported exposure and cotinine levels in a subset of this cohort indicated that self-reported ETS exposure was useful for categorizing relative exposure.[13] In addition, cotinine level represents exposure over only the previous 2 to 3 days, whereas the participants in this study self-reported on their usual exposure, which is more relevant for long-term health outcomes such as cancer and heart disease. Cotinine levels are also unable to provide information about the specific settings in which ETS exposure occurs, which is important for potential interventions, and is attainable through self-reported questionnaires. Our cotinine-validated questionnaire and classification scheme for ETS exposure accounted for exposure in each of three specific settings, which is important because neglecting exposure outside the home may lead to underestimation of total ETS exposure.[17] This is a large, prospective, population-based cohort with consistently high participation rates. The current analyses were limited to those with data at both time points in order to examine change in ETS among the same group of individuals, unlike the NHANES design which utilizes serial cross-sectional samples. However, the vast majority of this population is non-Hispanic white, and results may not be generalizable to minority groups.

Conclusions

Self-reported ETS exposure in this population-based cohort of older adults decreased between 1998–2000 and 2003–2005. For exposure in social settings and the home, later time period was associated with lower odds of exposure, adjusted for age and other covariates.

Decreased ETS exposure among older adults may contribute to declines in ETS-related adverse health outcomes such as heart disease.

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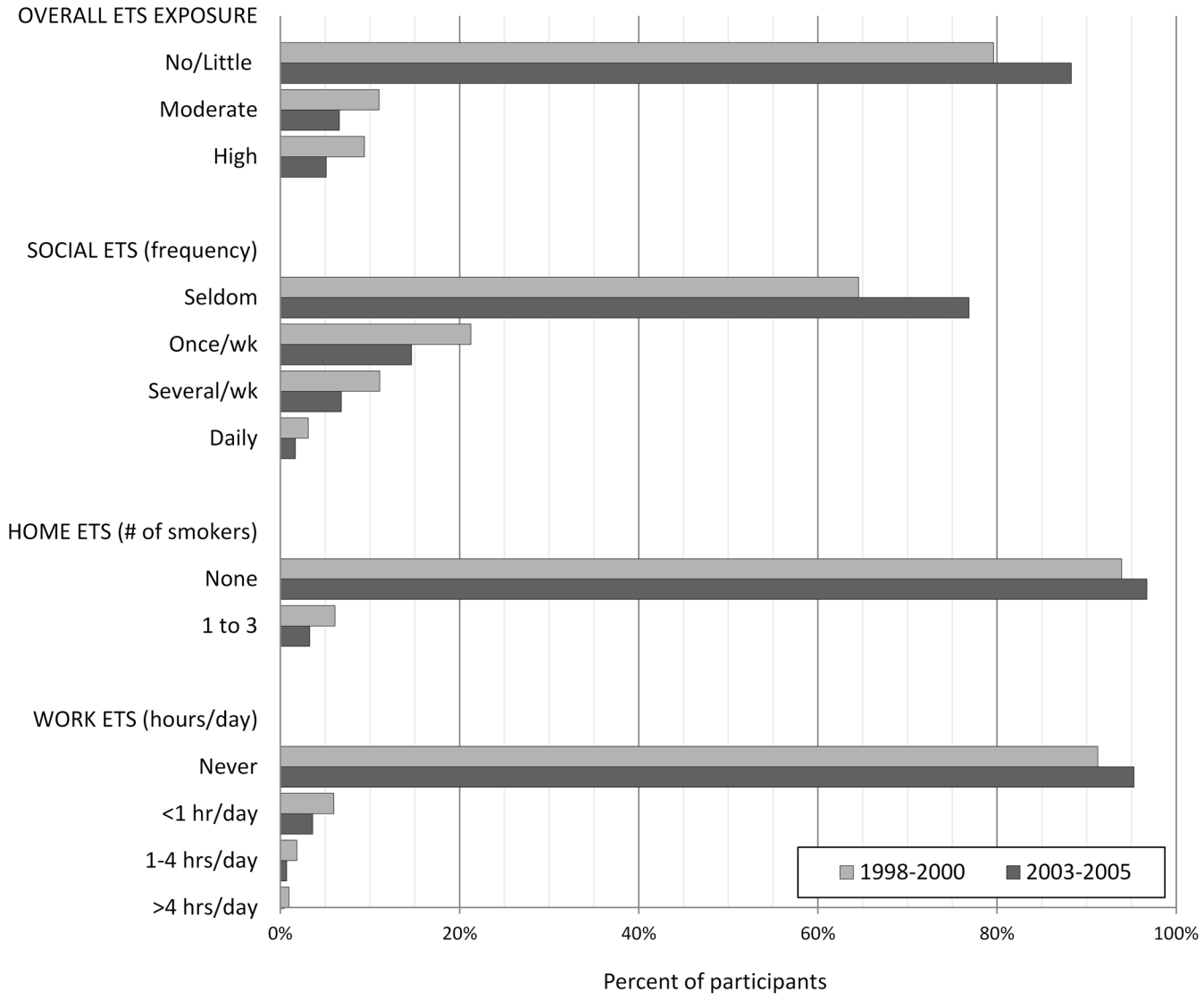

Figure 1.
Unadjusted ETS exposure (%) by time period, overall and in each setting.

Table 1

Participant characteristics by time period (n=1898).

	1998–2000	2003–2005
	n (%)	
Sex (female)	1151 (60.6)	Time invariant
Age (years)		
53–59	442 (23.3)	55 (2.9)
60–69	671 (35.4)	762 (40.2)
70–79	566 (29.8)	606 (31.9)
80–89	204 (10.8)	401 (21.1)
90–100	15 (0.8)	74 (3.9)
Education (years)		
< 12	300 (15.8)	Time invariant
12	921 (48.6)	---
13–15	330 (17.4)	---
≥ 16	345 (18.2)	---
Marital status		
Never married	66 (3.6)	64 (3.6)
Separated/Divorced	136 (7.3)	130 (7.2)
Widowed	370 (20.0)	471 (26.2)
Married	1280 (69.1)	1133 (63.0)
No. others living in home		
None	452 (24.0)	516 (28.4)
1	1198 (63.6)	1165 (64.1)
2	179 (9.5)	99 (5.4)
≥ 3	54 (2.9)	38 (2.1)
Employed		
Full-time	476 (25.1)	254 (13.4)
Part-time	257 (13.5)	250 (13.2)
Not employed	1165 (61.4)	1394 (73.4)

Table 2

Adjusted odds ratios for ETS exposure by relevant participant characteristics [OR (95% CI)].

	Overall ETS	Social ETS	Home ETS	Work ETS [a]
Later time period	0.62 (0.53, 0.73) *	0.69 (0.61, 0.78) *	0.65 (0.51, 0.83) *	1.15 (0.77, 1.72)
Age (per 5 years)	0.87 (0.81, 0.94) *	0.24 (0.18, 0.31) *	0.62 (0.34, 1.13)	0.23 (0.07, 0.77) *
Female sex	0.41 (0.33, 0.51) *	0.52 (0.44, 0.62) *	0.71 (0.48, 1.05)	0.18 (0.11, 0.29) *
College (vs. < h.s.)	0.25 (0.16, 0.37) *	0.57 (0.42, 0.77) *	0.40 (0.19, 0.87) *	0.20 (0.09, 0.45) *
Some college (vs. < h.s.)	0.65 (0.46, 0.92) *	0.85 (0.63, 1.15)	1.32 (0.71, 2.44)	0.46 (0.21, 0.98) *
High school (vs. < h.s.)	0.53 (0.40, 0.71) *	0.95 (0.74, 1.22)	0.78 (0.44, 1.37)	0.52 (0.26, 1.05)
Currently working	1.44 (1.14, 1.83) *	---	---	---
Lives with others (per each)	1.12 (0.99, 1.26)	---	1.53 (1.08, 2.18) *	---

h.s. = high school; ETS = environmental tobacco smoke; GEE = generalized estimating equations; OR = odds ratio; CI = confidence interval (a) Analysis for work ETS was restricted to those working part- or full-time at both time points (n=350).

* $p < 0.05$