REVIEW

Exposure to secondhand smoke and excess lung cancer mortality risk among workers in the "5 B's": bars, bowling alleys, billiard halls, betting establishments, and bingo parlours

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Tobacco Control 2003;**12**:333–338

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Received 16 December 2002
Accepted 21 June 2003

Objective: To review existing data on exposure to secondhand smoke in bars, bowling alleys, billiard halls, betting establishments, and bingo parlours (the "5 B's") as assessed by ambient nicotine air concentration measurements and to estimate the excess lung cancer mortality risk associated with this exposure.
Data sources: Using the Medline, Toxline, and Toxnet databases, the internet, and bibliographies of relevant articles, we identified studies that reported measurements of ambient nicotine concentrations in the 5 B's.
Study selection: Studies were included if they reported a mean concentration of ambient nicotine measured in at least one of the 5 B's.
Data extraction: We calculated a weighted average of nicotine concentrations in each of the 5 B's. We then estimated the working lifetime excess lung cancer mortality risk associated with this exposure, as well as with exposure at the upper and lower limits of the range of mean exposures reported in all of the studies in each establishment category.
Data synthesis: Nicotine concentrations in the 5 B's were 2.4 to 18.5 times higher than in offices or residences, and 1.5 to 11.7 times higher than in restaurants. At these exposure levels, estimated working lifetime excess lung cancer mortality risk from secondhand smoke exposure for workers in the 5 B's is between 1.0–4.1/1000, which greatly exceeds the typical de manifestis risk level of 0.3/1000.
Conclusions: Workers in the 5 B's have high levels of occupational exposure to secondhand smoke and must be included in workplace smoking regulations.

Over the past few decades, there have been three overlapping waves in the focus of clean indoor air policy in the USA. In the first wave, policy makers aimed to protect the public from secondhand smoke exposure in public places, such as elevators, movie theatres, retail stores, and public buildings. The second wave of smoking regulations targeted the workplace, but focused on office buildings while exempting service workplaces, such as restaurants and bars. In the third and current wave, attention is finally being given to the service workplace; however, the focus is almost entirely on restaurants, largely ignoring establishments such as bars, bowling alleys, billiard halls, betting establishments, and bingo parlours, which we will term the "5 B's."

Because of this pattern of policy focus, protection of workers from secondhand smoke exposure varies by workplace type. For example, of the 1388 local clean indoor air ordinances in the USA as of May 2002, 75% regulated smoking in workplaces and 67% regulated smoking in restaurants, but only 8% regulated smoking in bars.[1] Similarly, 45 states restrict smoking in workplaces and 30 restrict smoking in restaurants,[2] but as of July 2003, only five have enacted legislation that regulates smoking in bars. Because of this pattern of clean indoor air policy adoption, workers in service workplaces, particularly the 5 B's, do not enjoy the same level of protection from secondhand smoke exposure as the public or those who work in office settings. One reason why these service type establishments have largely been exempt from regulation is the relationship that exists between these establishments and the tobacco industry and the support that the industry has provided to them to help them oppose smoking regulations.[3 4]

Given the lack of protection of workers in the 5 B's, a formal review of the exposure levels and potential health effects of secondhand smoke among these workers is critical; however, we are unaware of any such published review. In 1993, Siegel reviewed the exposure levels and health effects among restaurant and bar workers, reporting that these workers were exposed to substantially higher levels of secondhand smoke than office workers, and concluding that secondhand smoke is a significant occupational health hazard for these workers.[5] Ten years later, while there have been substantial advances in restaurant smoking regulations, little progress has been made in protecting bar workers and it is now clear that there are additional service workers—those in the other 4 B's—who have been neglected. In the USA, there are more than 800 000 workers in bars, bowling alleys, and casinos alone.[6–8] It is therefore time to re-examine the exposure levels and resulting health effects for bar workers and to include workers in bowling alleys, billiard halls, betting establishments, and bingo parlours in order to help guide the future development of clean indoor air policy.

In this paper, we conduct a literature review on secondhand smoke exposure in bars, bowling alleys, billiard halls, betting establishments, and bingo parlours in order to: (1) compare average levels of exposure to secondhand smoke in the 5 B's, as measured by indoor air concentrations of nicotine, to levels of exposure in offices, homes, and restaurants; and (2) estimate the lifetime excess lung cancer mortality risk associated with secondhand smoke exposure among workers in the 5 B's. Because of the small number of studies that have examined secondhand smoke exposure in the 5 B's (and thus the high variability of the existing data), we provide both a point

estimate and an estimate of the lower and upper bound of the plausible range of exposure and mortality risk.

METHODS

Indoor air concentrations of nicotine

We conducted a literature search to identify studies that reported measurements of tobacco constituents in indoor air in free-standing bars, bowling alleys, billiard halls, betting establishments (including casinos and smaller betting shops), and bingo parlours. Three databases—Medline, Toxline, and Toxnet—were searched to identify published studies, and bibliographies from each publication were reviewed to identify additional relevant articles. An internet search was conducted to identify studies published online and to identify additional published studies that may have been missed through the database searches. Additionally, we analysed several published reviews that summarised measurements of tobacco constituents in indoor air, including those by Sterling *et al*,[9] Repace,[10] Repace and Lowrey,[11 12] Hammond,[13] and Guerin.[14]

For the database searches, our search terms were: nicotine (as keyword or subject heading) AND smoke (as keyword or subject heading, or with tobacco smoke pollution as subject heading) AND any one of the following terms: bar, club, nightclub, tavern, pub, billiard, pool, bowling, betting, gambling, casino, or bingo. We also conducted a search that did not require any of the establishment terms but added any one of the terms: measurement, level, or air. For the internet search, we used the Google search engine and searched the first 500 websites obtained by using the search terms nicotine AND smoke AND any of the establishment terms. In addition, we searched all websites using the search terms nicotine AND smoke, and requiring these terms to be in the page title.

Studies were included if they reported the mean concentration of nicotine, obtained via either stationary or personal breathing zone monitors, from measurements taken in one or more worksites within the 5 B's. We defined bars as being free-standing establishments; bar areas of restaurants were not included in this definition. Studies that did not measure nicotine concentrations, or that reported only a range of values without providing data from which a mean could be calculated, were not included in our calculations of mean nicotine concentrations. We identified a total of 18 studies that met these criteria.[15–33]

Because of the possibility of variations in tobacco smoke exposure levels across countries, we included in this analysis only the 13 studies conducted in the USA. Excluded from the analysis, therefore, was one study of bars in England,[17] one study of pubs in Japan,[21] a study of betting establishments in England,[27] a study of bars and nightclubs in Canada,[32] and a bar study in France.[33] However, results from these five studies are similar to those from the US studies, and excluding these studies from the analysis would not have appreciably affected the findings. For comparison purposes, we do present the results of the analyses with inclusion of the non-US studies in the results section; however, the tables and remaining text present results of the US studies only.

A weighted average of the mean nicotine concentrations reported in each of the studies was calculated for each of the 5 B's. The weight given to each study was the number of establishments sampled. These weighted mean nicotine concentrations were compared to weighted mean concentrations calculated in a similar manner for offices, residences, and restaurants that were reported in a previous study.[5] It should be noted that this earlier study included only measurements taken in establishments where smoking was allowed. Weighting by the number of establishments rather than the inverse of the variance within each study was chosen because we desired our results to be less sensitive to a small number of very large studies that conducted multiple measurements within a given establishment (and thus achieved very low variance levels). In addition, weighting by the number of establishments allowed us to include all the identified studies, even those for which a variance estimate was not reported. Finally, using this weighting procedure allowed comparability with our previous review,[5] which enabled us to compare estimates in the 5 B's with those in offices, homes, and restaurants.

Because of the variability of nicotine measurements in the different studies, we felt it important to provide not only an estimate of average exposure, but also an indication of the range of reported exposures. Therefore, we report both the weighted mean nicotine concentrations for each type of establishment and the range of mean nicotine concentrations obtained in all of the studies within each establishment category. Our subsequent lung cancer mortality estimates are then based not only on the mean exposure level, but also on the low and high end of the range of mean exposures reported for the establishments of a given type.

Estimates of excess lung cancer mortality risk

To interpret the potential health effects of secondhand smoke exposure at the levels observed for workers in the 5 B's, we estimated the excess lifetime lung cancer mortality risk for workers in each type of establishment, based on the weighted mean nicotine concentrations in these workplaces and on the low and high end of the range of mean nicotine concentrations reported in all of the studies of these workplaces. Thus, we provide not only a point estimate of predicted excess mortality risk, but a lower and upper bound estimate based on the full range of mean nicotine values reported in the literature.

Lifetime excess lung cancer mortality risk estimates were derived from ambient nicotine concentrations using a formula developed by Repace and Lowrey.[12] This formula estimates excess lung cancer mortality risk over a 40 year working lifetime based on air nicotine concentrations. The risk model on which this formula is based was successful in predicting actual lung cancer risks observed in the Cancer Prevention Study (CPS-I) and its use is discussed and validated by a number of secondhand smoke risk analysis experts.[34] We are not aware of any alternative model that outperforms this method or is based on a better risk model. Alternative methods for estimating non-smokers' excess lung cancer risk based on varying dose–response models have been discussed[35]; however, each of these models produces very similar excess lung cancer risk estimates.[35] We therefore have no reason to believe that the Repace and Lowrey model[12] is not a representative and valid one.

Although Repace *et al* have estimated excess heart disease mortality risk from ambient nicotine levels by multiplying the lung cancer mortality risk by a factor of 10:1,[34 36] we do not estimate excess heart disease mortality risk here, as the time course of these effects is vastly different and a simple linear extrapolation of risk may not be adequate to capture accurately the heart disease risk profile.

We assumed an eight hour per day, five day work week for workers in each of the 5 B's, except for bingo parlour workers, for whom we assumed exposure for a two hour shift twice a week. This assumption is based on our experience of the hours during which bingo parlours typically operate; we are not aware of published data that review the working hours of employees in bingo parlours. Similarly, our experience suggests that a 40 hour work week is a reasonable assumption for workers in each of the other 4 B's, although we are not aware of data that document this.

We estimate excess lung cancer mortality risk over a 40 year working lifetime. It should be noted that many bar workers probably work in these establishments for far less than 40 years. However, our feeling is that an assessment of risk should be based on what the long term risk of working in an establishment over one's working lifetime would be, rather than on the issue of whether transient exposures would be

Table 1 Indoor air concentrations on nicotine (μg/m³) in a variety of workplaces

Type of workplace	Number of studies	Number of establishments sampled	Weighted mean*	Range	Ratio†
Offices[5]	22	940	4.1	0.8–22.1	1.0
Residences[5]	7	91	4.3	1.6–21.0	1.0
Restaurants[5]	17	402	6.5	3.4–34.0	1.6
Betting establishments[12 14 22 28–30]	3	4	9.8	8.0–10.7	2.4
Bowling alleys[11 22 23]	2	6	10.5	10.1–10.7	2.6
Billiard halls[14 23 26]	2	3	13.0	9.8–19.4	3.2
Bars[14–16 18–20 22–25 31]	10	27	31.1	7.4–105.4	7.6
Bingo parlours[23 28]	2	3	76.0	65.5–81.2	18.5

*Mean of average nicotine values reported in individual studies weighted by number of establishments sampled in each study.
†Ratio of weighted mean nicotine concentration in residences, restaurants, bowling alleys, billiard halls, betting establishments, bars, and bingo parlours to weighted mean nicotine concentration in offices.

expected to produce long term health effects. In other words, one could argue that no matter how high the exposure is in bars, if bartenders tend to work in this occupation only for several years, their long term cancer risk may not be particularly high. We do not find this argument to be compelling; we believe that policy decisions must be based on an assessment of the safety of the working conditions over a long period, and the lowered risk among short term workers should not change one's assessment of the risks. Moreover, a large number of workers do invariably work in these establishments for their working lifetimes. Therefore, we estimate excess risks for a full 40 year working lifetime.

RESULTS

Indoor air concentrations of nicotine

The weighted mean air nicotine concentration in bars, bowling alleys, billiard halls, betting establishments, and bingo parlours ranged from 9.8 μg/m³ to 76.0 μg/m³, representing exposure levels that are 2.4 to 18.5 times higher than in offices or residences and 1.5 to 11.7 times higher than in restaurants (table 1). The lowest mean nicotine concentration in any individual study for any of the 5 B's was 7.4 μg/m³, which is higher than the average exposure level for restaurants (6.5 μg/m³) and nearly twice the average level for offices (4.1 μg/m³). The highest mean nicotine level in any individual study was 105.4 μg/m³, measured in a nightclub, and representing an exposure level 16.2 times higher than the average level in restaurants.

Although there were only two studies that reported nicotine concentrations in each of three establishment types—bowling alleys, billiard halls, and bingo parlours—it should be noted that the results of these studies were quite consistent in each category. In addition, despite the variability of the exposure estimates because of the small number of studies, the low end of the range of reported mean nicotine concentrations for each of the 5 B's exceeds the weighted mean nicotine concentration in offices by a factor of 1.8 (for bars) to 16.0 (for bingo parlours), and exceeds the average nicotine concentration in restaurants by a factor of 1.1 to 10.1.

Two identified studies[37–39] were not included in table 1 because they did not meet our inclusion criteria—one[37] reported only a range of nicotine values and the other[38 39] did not separate measurements taken in free-standing bars from those taken in bar areas of restaurants. However, both study results were consistent with values reported in table 1. Coghlin *et al*[37] found that nicotine concentrations in bars ranged from 6–82 μg/m³, in a bowling alley ranged from 13–20 μg/m³, and in a bingo hall ranged from 53–60 μg/m³. The largest study of nicotine values in bars, which reported measurements from 49 establishments,[38 39] reported a mean nicotine concentration of 14.4 μg/m³ in bars and bar areas of restaurants. This is consistent with values reported in table 1, especially in light of the fact that measurements in bar areas of restaurants are likely to be lower than in free-standing bars.

If non-US studies are included in the analysis, then the weighted mean nicotine concentration for bars increases from 31.1 μg/m³ to 39.3 μg/m³, and weighted mean nicotine concentration for betting establishments increases from 9.8 μg/m³ to 13.9 μg/m³. The lower values, with only US studies included, are used in subsequent lung cancer mortality risk estimates.

Estimates of excess lung cancer mortality risk

Estimated excess lifetime lung cancer mortality risk caused by workplace secondhand smoke exposure among workers in the 5 B's ranged from 0.0010–0.0041 (table 2). If correct, this

Table 2 Estimates of 40 year working lifetime excess mortality risk from lung cancer associated with secondhand smoke exposure among workers in bowling alleys, billiard halls, betting establishments, bars, and bingo parlours*

Type of workplace	Weighted mean nicotine concentrations (μg/m³) and range†	Lung cancer mortality risk	Lower range of mortality risk	Upper range of mortality risk
Betting establishments	9.8 (8.0–10.7)	0.0013	0.0011	0.0014
Bowling alleys	10.5 (10.1–10.7)	0.0014	0.0013	0.0014
Billiard halls	13.0 (9.8–19.4)	0.0017	0.0013	0.0026
Bars	31.1 (7.4–105.4)	0.0041	0.0010	0.0140
Bingo parlours	76.0 (65.5–81.2)	0.0010‡	0.0009	0.0011

*Mortality risk estimated using method developed by Repace and Lowrey[12] for ambient nicotine values. For bingo workers, 2 hours of exposure twice a week are assumed, compared to a 40 hour work week for all other workers. Note that although the estimates are based on a working life (40 years) of exposure, the excess deaths could occur post-working life.
†Weighted mean nicotine concentrations are from table 1. Range represents range of mean nicotine concentrations from individual studies.
‡Assumes 2 hours of exposure twice a week.

means that between 1.0–4.1 of every 1000 workers in these establishments who works for 40 years will die of lung cancer attributable to their workplace secondhand smoke exposure. All of these mortality risks greatly exceed even the typical de manifestis (a risk level so high that the involuntary hazards are invariably of regulatory concern and the federal government strictly regulates a carcinogen[12]) risk level of 0.0003, or 0.3/1000. Under the highest exposure conditions in bars, we estimate that approximately 14 of every 1000 workers will die from lung cancer attributable to their worksite exposure (assuming 40 years of exposure in that worksite).

Importantly, the lower limit of the range of estimated lifetime excess lung cancer mortality risk for the 5 B's based on the identified studies is between 0.9–1.3/1000, or approximately three to four times higher than the typical de manifestis risk level.

Through our literature search, we identified two previous studies that estimated excess lifetime mortality risk among bar or restaurant workers caused by secondhand smoke exposure. Repace estimated a working excess lifetime mortality risk of 0.03 (three deaths per hundred workers) for Hong Kong restaurant workers[36] and 0.20 (20 deaths per hundred workers) for Irish bar workers.[40] Since Repace included heart disease deaths (at a level 10 times that of lung cancer deaths), his estimates for excess lung cancer mortality risk amount to approximately 0.0027 for Hong Kong restaurant workers and 0.018 for Irish bar workers. The former estimate is entirely consistent with the range of excess mortality estimates presented in this paper (considering that exposure in bars would be expected to be higher than for restaurants); the latter estimate is just slightly higher than our excess mortality estimate for the most heavily contaminated bar in our analysis.

DISCUSSION

To the best of our knowledge, this is the first review of exposure to secondhand smoke among workers in bars, bowling alleys, billiard halls, betting establishments, and bingo parlours. We found that ambient nicotine concentrations in these establishments were 2.4 to 18.5 times higher than in offices and 1.5 to 11.7 times higher than in restaurants. Even in the lowest exposure conditions (the lower limit of the range of mean nicotine concentrations in all identified studies), nicotine concentrations in the 5 B's exceeded those in offices by a factor of 1.8 to 16.0 and exceeded values in restaurants by a factor of 1.1 to 10.1. Thus, despite the high variability in exposure levels due to the small number of studies, the basic conclusion that the 5 B's represent worksites with very high relative occupational levels of secondhand smoke exposure seems to be clear.

The high levels of secondhand smoke exposure in the 5 B's translates into lifetime excess lung cancer risk estimates that exceed the typical de manifestis risk level, even for the lower limit of the range of observed exposures in these establishments. Based on the average exposure conditions, we estimate lifetime excess lung cancer mortality risk of between 1.0–4.1/1000 (compared to the typical de manifestis risk level of 0.3/1000). However, under the highest exposure conditions for any of the 5 B's, workers are exposed to concentrations of nicotine that are about 26 times higher than in offices, resulting in an estimated excess lifetime lung cancer mortality risk of 1.4% (and 47 times the de manifestis risk level).

The data presented here suggest that the focus of clean indoor air policy promotion should shift to include all service workplaces, including not only restaurants, but the 5 B's as well. We found that nicotine concentrations in the 5 B's exceed those in restaurants by a factor of 1.5 to 11.7. Given that Wortley *et al*[41] found waiters and waitresses to have the highest serum cotinine concentrations of any occupational group (data for workers in the 5 B's were not reported separately), this suggests that workers in the 5 B's are actually the occupational groups most heavily exposed to secondhand smoke in the workplace.

An important implication of our findings is that the current pattern of workplace smoking regulations is fostering a disparity in health protection between various types of workers. Data from the US Census suggest that this could translate into a social class disparity in health protection among workers, since the average annual salaries of workers (including both full time and part time employees and not including tip income) in bars ($9661),[42] betting establishments ($19 117),[43] and bowling alleys ($9 325)[43] are much lower than the national average ($32 109)[42] (also including full time and part time employees) for all industries. Although Healthy People 2010 calls for the reduction of secondhand smoke exposure in the workplace,[44] it also calls for the elimination of health disparities between groups on the basis of social class.[45] It may be that extending protection from secondhand smoke exposure to service workers in the 5 B's may help promote not only the Healthy People 2010 goal of reducing workplace secondhand smoke exposure, but also its goal of reducing health disparities.

Study limitations

There are several important limitations of this paper. The primary limitation is that few studies examined exposure to secondhand smoke among workers in the 5 B's, especially bowling alleys, billiard halls, and bingo parlours, for which there were only two identified exposure studies each. Therefore, there is great variability in the estimates of secondhand smoke exposure levels (and consequently, in the lung cancer mortality risk estimates). Our approach was to provide a range of exposure and risk estimates corresponding to the lowest and highest mean nicotine concentrations reported in all of the identified studies for each type of establishment. We suggest that the most appropriate interpretation of the results of our study is not to cite specific exposure and risk levels as being the truth, but to document the qualitative conclusion (supported by even the lowest exposure and risk estimates) that secondhand smoke exposure in the 5 B's exceeds that for most other workplaces, and that the resulting excess lung cancer mortality risk exceeds the level at which carcinogens are typically strictly regulated.

A second limitation is that we most likely were not successful in obtaining all of the studies that would have met our inclusion criteria. We reason that we were probably more successful in obtaining published articles than unpublished ones, given our use of database search facilities with extensive journal coverage. It is important to note, however, that unlike typical publication bias, where negative studies are less likely to be published, there really is no "negative" result when it comes to reporting nicotine concentrations in workplaces. Thus, even though we may not have been exhaustive in our inclusion of studies, we have no reason to believe that our sample is not representative of all studies.

A third important limitation is that although we estimated lung cancer mortality risks, the number of heart disease deaths attributable to secondhand smoke exposure far exceeds the number of lung cancer deaths. Our risk estimates therefore greatly underestimate the total mortality burden attributable to secondhand smoke exposure in the 5 B's. Our estimates may in fact underestimate the total disease burden by a factor of 10.[34 36]

Finally, our mortality estimates are based on the assumption of a 40 year working period. There may be reason to believe that bar workers, for example, represent a more transient occupational group than other types of workers and may be less likely to experience exposure over many years. Nevertheless, it is important to point out that while the actual mortality risks may therefore be lower, the assessment of the

What this paper adds

While levels of exposure to secondhand smoke among restaurant workers have been reviewed, we are not aware of any published review of exposure among workers in bars, bowling alleys, billiard halls, betting establishments, and bingo parlours (the "5 B's"). Since workers in these establishments are typically excluded from workplace smoking regulations (which usually cover office workplaces and sometimes cover restaurants), it is critical to understand and evaluate their secondhand smoke exposure and associated health risks.

From this review, we now know that workers in these five types of establishments have extremely high levels of occupational exposure to secondhand smoke. We have quantified the average exposure levels and estimated the resulting lifetime lung cancer mortality risk among these workers, and have provided a range of exposure and mortality estimates corresponding to the range of nicotine concentrations measured in these establishments. While public health advocates must continue to seek protection of the public from secondhand smoke exposure in office workplaces and restaurants, they must devote special attention to protecting workers in these five service workplaces.

level of occupational risk for these workers should be based on whether it would be safe for them to work under such conditions for a working lifetime (which many bar workers invariably do). Thus, we believe that presenting working lifetime mortality estimates is the most useful and appropriate measure to judge the occupational health risk. It should be noted that because the risk model is linear, one can derive risk estimates for shorter working periods directly from the estimates in table 2.

Conclusion

In spite of these limitations, this review of secondhand smoke exposure in bars, bowling alleys, billiard halls, betting establishments, and bingo parlours suggests that workers in these establishments have the highest occupational levels of exposure to secondhand smoke, resulting in unacceptable levels of excess mortality risk. Unfortunately, these tend to be the workers most often excluded from workplace smoking regulations. Perhaps it is now time for a fourth wave of clean indoor air policy promotion, in which public health advocates insist that workers in the 5 B's be extended the protection that the majority[1 2] of other workers benefit from.

ACKNOWLEDGEMENTS

This work was supported by a grant from the Flight Attendant Medical Research Institute. The authors wish to thank the reviewers for their very helpful comments on the manuscript.

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"Mellow" heart disease? *Time* magazine runs a cover story on women and heart disease, explaining "What you can do to protect yourself!" The story is well written, providing several reminders that women need to "walk a mile" away from a Camel, or any other cigarette. But the back cover tells a different story. A picture destroying the value of many thousand words. Submitted by Ron Davis.