Secondhand smoke exposure ($PM_{2.5}$) in outdoor dining areas and its correlates

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Tob Control 2010 19: 19-23 originally published online October 21, 2009
doi: 10.1136/tc.2009.030544

Secondhand smoke exposure ($PM_{2.5}$) in outdoor dining areas and its correlates

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Received 24 March 2009
Accepted 23 September 2009
Published Online First
21 October 2009

ABSTRACT

Background This study assessed the magnitude of secondhand smoke (SHS) exposure when people smoke in outdoor dining areas and explored conditions influencing exposure levels.

Methods Data were gathered from 69 outdoor dining areas in Melbourne, Australia, during April/May 2007. Sitting at tables within 1 metre of an active smoker, the authors measured the concentration of particulate pollution ($PM_{2.5}$) using TSI SidePak Personal Aerosol Monitors. $PM_{2.5}$ data were recorded by the monitor at 30-second intervals, and data were collected over an average of 25.8 minutes per venue. Information was collected about the presence of overhead coverings and the number of patrons and lit cigarettes.

Results The average background level of $PM_{2.5}$ was 8.4 $\mu g/m^3$ (geometric mean (GM)=6.1 $\mu g/m^3$), increasing to an average of 17.6 $\mu g/m^3$ (GM=12.7 $\mu g/m^3$) over the observational period and 27.3 $\mu g/m^3$ (GM=17.6 $\mu g/m^3$) during the time that cigarettes were actively smoked near the monitor. There was substantial variation in exposure levels, with a maximum peak concentration of 483.9 $\mu g/m^3$ when there were lit cigarettes close to the monitor. Average exposure levels increased by around 30% for every additional active smoker within 1 metre of the monitor. Being situated under an overhead cover increased average exposure by around 50%.

Conclusions When individuals sit in outdoor dining venues where smokers are present it is possible that they will be exposed to substantial SHS levels. Significant increases in exposure were observed when monitors were located under overhead covers, and as the number of nearby smokers increased. The role of outdoor smoking restrictions in minimising exposure to SHS must be considered.

INTRODUCTION

The link between exposure to secondhand smoke (SHS) and increased risk of acute symptoms and chronic diseases is well established,[1–4] and in 2006 the US Surgeon General concluded that "the scientific evidence indicates that there is no risk-free level of exposure to secondhand smoke".[4] As such, the World Health Organization, the US Environmental Protection Agency and the Australian National Environment Protection Council have all set standards for ambient exposure to particulate matter that is smaller than 2.5 μm in diameter.[5–7] Particulate matter of this size ($PM_{2.5}$) is released in substantial amounts from burning cigarettes, such that the concentration of $PM_{2.5}$ is a useful indicator of the concentration of SHS.

SHS exposure is of particular concern for people working in the hospitality industry, as they experience some of the highest levels of occupational SHS exposure.[8 9] These high exposures have been linked to respiratory symptoms and poor lung function among hospitality workers.[10–12] As such, over the last decade an increasing number of nations have implemented comprehensive smoke-free legislation in indoor public places with the aim of improving air quality and protecting the health of workers and patrons.[13] In Victoria, Australia, indoor dining areas and restaurants have been smoke-free since July 2001,[14 15] and indoor areas of bars and pubs became smoke-free in July 2007.[16] However, outdoor dining and drinking areas of bars, pubs and restaurants are not required to be smoke-free, unless the outdoor area has a roof in place and the total area of the wall surface exceeds 75% of the total notional wall area.[16] Under these requirements, outdoor dining areas where smoking is permitted can have varying degrees of enclosure.

SHS exposure in outdoor environments has only recently begun to be empirically investigated, with early findings indicating that outdoor SHS levels can be comparable to, or even higher than, indoor levels under specific conditions.[17 18] However, outdoor SHS concentrations are more variable than indoor concentrations, because SHS does not readily accumulate in outdoor environments and is sensitive to wind conditions.[18 19] Restrictions on smoking in outdoor dining areas have recently been introduced in the Australian states of Queensland and Tasmania.[20 21] There are several arguments both for and against such restrictions,[22–26] with the main concern being insufficient evidence of a health impact to warrant regulation. On the other hand, recent findings indicate significant SHS exposure levels in outdoor areas,[17 18] and there is increasing public support for restrictions.[27] Thus, further investigation of exposure to SHS in outdoor public places is warranted.

The aim of our study was to assess the potential magnitude of SHS exposure when people smoke in outdoor dining areas, and to explore the conditions influencing these exposure levels. We were particularly interested in the impact on exposure levels of sitting underneath an overhead cover or roof.

METHODS

Data collection procedure

Data collection occurred over 13 weekdays in April/May 2007 by trained research assistants. Eligible outdoor dining areas of restaurants and cafés were a defined area on the footpath where drinks and/or meals were served to patrons. All of these venues primarily served adults. Research assistants visited these areas during busy times (late morning, lunch and dinner periods), and spent approximately 30 minutes at each venue.

We selected a convenience sample of five shopping or retail areas within a 6-km radius of Melbourne city centre. Upon arriving at the shopping area, researchers looked for a patron sitting in an outdoor dining area who was either currently smoking a cigarette or had a packet of cigarettes in full view on the table, and who had an available dining table within 1 metre of where they were sitting. The researcher sat at the available table, and data collection began immediately if the person was already smoking, or when they lit their first cigarette (a 'target cigarette'). If no target cigarette was smoked within 30 minutes of arriving, the researcher left the venue. Researchers continued collecting data at the venue for 10 minutes after the target cigarette was extinguished. However, if a second and/or third target cigarette was lit within 10 minutes of the previous one being extinguished, then the researcher remained at the venue and continued collecting data until 10 minutes after the second/third target cigarette was extinguished, at which time the researcher left the venue. Researchers visited three or four venues per data collection session. To measure air quality in outdoor dining areas under natural conditions, several measures were taken to ensure that data collection was undetected by owners and patrons.[28] Researchers purchased either one non-alcoholic drink or a light meal at each venue, observational data were collected using a discrete notebook and the air quality monitor was concealed in a carry bag (see details below).

At the beginning of each data collection session, a 5-minute sample of baseline air quality data was collected from an area on the footpath away from crowds and smokers. This 5-minute sample of data served as the baseline level of exposure for all venues visited during that session.

Air quality data

The concentration in the air of particulate matter smaller than 2.5 μm in diameter ($PM_{2.5}$), served as the indicator of air quality. Air quality data at each venue were collected using a TSI SidePak AM510 Personal Aerosol Monitor. Before each data collection session the SidePak was charged, cleaned and zero-calibrated using the Hepa filter and standard calibration procedure.[29 30] The SidePak was fitted with a 2.5 μm impactor to measure the concentration of particulate matter less than or equal to 2.5 μm in diameter. A standard calibration factor of 0.32 was applied to the raw data to correct for the properties of SHS.[17 29 31 32] Although only one monitor collected data at each venue, two separate SidePaks were used in this study to allow concurrent data collection sessions. As such, an additional adjustment factor was applied to the raw data from each monitor to account for the mean differences between the two monitors, as calculated by a series of side-by-side experiments comparing the monitors in various environments (across measurements, the difference between monitors was less than 10%). Data were recorded by the SidePaks at 30-second intervals, with each 30-second data point being an average of the previous 30 one-second measurements.

To facilitate unobtrusive data collection, a length of Tygon tubing was attached to the inlet of the SidePak, and the SidePak was placed in a camera-like carry bag with the tubing protruded from the bag by only 1 inch. The bag containing the SidePak was situated on top of the table for the entire data collection period.

Observational data

Observational data collected at 5-minute intervals included the number of other lit cigarettes at the venue (ie, apart from the target cigarettes, but including other cigarettes smoked at tables in close proximity to the researcher), and whether or not the SidePak was located underneath an overhead cover. Overhead covers included umbrellas, shade cloth, building awnings and roofing. Trees were not included. Further observational data collected only once per venue included the presence and height of side walls; measures of the number of patrons in the area; whether or not meals were being served or eaten in the outdoor area; and a sketch of the layout of the venue, noting the location of the monitor and the location of any major barriers to air flow. Researchers also noted the exact time at which each target cigarette was lit and extinguished.

Statistical analysis

Two outcome measures were derived from the air quality data collected at each venue: (1) total time exposure, referring to average $PM_{2.5}$ exposure levels detected over the entire time spent at the venue; and (2) cigarette time exposure, referring to average $PM_{2.5}$ exposure levels detected during the time that target cigarettes were being smoked at the venue. In addition, a measure of baseline $PM_{2.5}$ exposure was obtained for each venue. Because this air quality data are positively skewed, all statistical analyses were performed using log-transformed dependent variables, and geometric means (GM) are reported in addition to arithmetic means (mean) to ensure comparability of our results with previous research in this field.

Observational data about the overhead cover and wall coverings at each venue were combined to establish various categorical variables describing the degree of enclosure at venues. However, preliminary analyses indicated that a distinction between venues at which the monitor was and was not located underneath an overhead cover (regardless of wall height) provided the most robust findings, and only these results are presented here.

Multivariate linear regression analyses were conducted to examine the relation between the two outcome measures (total time and cigarette time exposure) and the predictor variables expected to influence exposure levels (number of target cigarettes; number of other lit cigarettes; overhead cover). Baseline $PM_{2.5}$ exposure was entered as a covariate in all analyses.

RESULTS

Sample characteristics

Data were collected over 69 visits to 54 unique outdoor dining areas (one venue was visited on five separate occasions; one venue was visited four times; eight venues were visited twice). An intra-class correlation analysis indicated that there were no substantial effects of venue clustering on GM total time exposure (coefficient = 0.14; 95% CI 0.00 to 0.63; $F(2, 22) = 2.11$, $p = 0.15$), or on GM cigarette time exposure (coefficient = 0.06; 95% CI 0.00 to 0.44; $F(2, 22) = 1.38$, $p = 0.27$). Therefore, the 69 venue visits were treated as separate venues in the analyses.

Overall, data were collected for a mean of 25.8 minutes across venues (range 13.0–57.0 minutes). The mean time for which individual target cigarettes were lit was 6.3 minutes. Owing to multiple (two and/or three) target cigarettes at some venues, the cumulative average of target cigarette exposure was 9.9 minutes. Meals were being served or eaten during the data collection session at 90% (n=62) of venues, and the mean number of patrons at outdoor venues was 11.0 (range 2–33).

$PM_{2.5}$ exposure levels

The overall (n=69 venues) mean *baseline* $PM_{2.5}$ exposure was 8.4 $\mu g/m^3$ (95% CI 6.6 to 10.2; GM=6.1 $\mu g/m^3$, 95% CI 5.0 to 7.3).

The mean *total time* exposure was 17.6 μg/m^3 (95% CI 14.0 to 21.2; GM=12.7 μg/m^3, 95% CI 10.4 to 15.4), ranging from 2.7 μg/m^3 to 78.0 μg/m^3. In comparison, the mean *cigarette time* exposure was 27.3 μg/m^3 (95% CI 21.2 to 33.4; GM=17.6 μg/m^3, 95% CI 13.9 to 22.2), ranging from 2.6 μg/m^3 to 112.7 μg/m^3.

Peaks in $PM_{2.5}$ exposure at the 30-second level were generally much higher than mean exposure levels. During the times that target cigarettes were lit (cigarette time), the mean 30-second peak concentration across venues was 115.2 μg/m^3, while the maximum 30-second peak concentration was 483.9 μg/m^3. In contrast, during the times in which there were no lit target cigarettes at venues, the mean 30-second peak concentration across venues was 48.7 μg/m^3 and the maximum 30-second peak concentration was 297.7 μg/m^3.

Factors influencing $PM_{2.5}$ exposure levels

Number of close proximity ('target') cigarettes

More than half (58%) of venues had one target cigarette; 28% had two; and 14% had three target cigarettes. The number of target cigarettes significantly predicted exposure levels at the multivariate level, with every one unit increase in the number of target cigarettes increasing total time exposure by 34% (95% CI 10% to 63%; p=0.004), and cigarette time exposure by 34% (95% CI 2% to 75%; p=0.037). The wide confidence intervals for these significant effects illustrate the considerable variability in $PM_{2.5}$ exposure at these venues.

Number of other cigarettes (non-target cigarettes)

The average number of other lit cigarettes at venues ranged from 0 to 2.8, with an overall mean of 0.7. The number of other lit cigarettes did not significantly predict total time exposure at the multivariate level (p=0.261). During the time that target cigarettes were lit, the average number of other lit cigarettes at venues ranged from 0 to 4, with an overall mean of 0.9. Cigarette time exposure was significantly predicted by the number of other lit cigarettes, with every one unit increase in the number of other lit cigarettes at the venue increasing cigarette time exposure by 25% (95% CI 0.8% to 55%; p=0.042).

Overhead cover

Of the 69 venues visited, 71% had some overhead cover, while 29% either did not have an overhead cover or the monitor was not located under cover. The multivariate linear regressions indicated that being situated underneath an overhead cover increased total time exposure by 51% (95% CI 9% to 109%; p=0.014), and cigarette time exposure by 71% (95% CI 9% to 167%; p=0.020). Again, the wide confidence intervals for these significant effects illustrate the extent of variability in $PM_{2.5}$ exposure.

Variation in exposure levels at venues with low exposure and high exposure conditions

To further examine variations in the level of SHS exposure at outdoor dining areas, we selected one venue at which the conditions were favourable to low SHS exposure (one target cigarette; monitor not under cover), and one venue at which the conditions contributed to high exposure levels (three target cigarettes; monitor under cover). As illustrated in figure 1, exposure levels at the venue with low exposure conditions had a maximum peak of 17.7 μg/m^3 during the time that a target cigarette was lit, and a maximum peak of 7.8 μg/m^3 during the time that there were not any target cigarettes lit. In contrast, exposure levels at the venue with high exposure conditions spiked several times at around 400 μg/m^3, with a maximum peak of 483.9 μg/m^3 during the time that target cigarettes were lit, and a maximum peak of 191.4 μg/m^3 during the time that that there were not any target cigarettes lit (figure 1). While the difference in exposure levels at these two venues is partially explained by their different baseline levels (3.1 μg/m^3 mean baseline $PM_{2.5}$ at the low exposure venue, compared with 22.5 μg/m^3 mean baseline $PM_{2.5}$ at the venue with high exposure conditions) this does not fully account for the substantially greater exposure peaks observed at the high exposure venue. The data from these two venues further illustrate the effect of being situated underneath an overhead cover and being exposed to multiple close proximity cigarettes on exposure to SHS at outdoor dining areas, as well as illustrating the potential for high peaks in exposure.

DISCUSSION

Compared with the mean baseline exposure level of 8.4 μg/m^3 (GM=6.1 μg/m^3), the mean total exposure at outdoor dining areas where smokers were present was 17.6 μg/m^3 (GM=12.7 μg/m^3), and the mean exposure during those times that a target cigarette was lit was 27.3 μg/m^3 (GM=17.6 μg/m^3). There was substantial variation in exposure levels, with the potential for 30-second concentrations to reach almost 500 μg/m^3 at some venues.

Similar to the findings of Klepeis and colleagues,[18] the findings from this observational study suggest that outdoor concentrations of SHS can be comparable to those detected indoors, although lower overall outdoor concentrations are often observed because outdoor concentrations are more susceptible to the proximity of the cigarettes and to rapid dissipation. Nonetheless, when an individual sits in an outdoor dining area where smokers are present, it is possible that they will be exposed to substantial

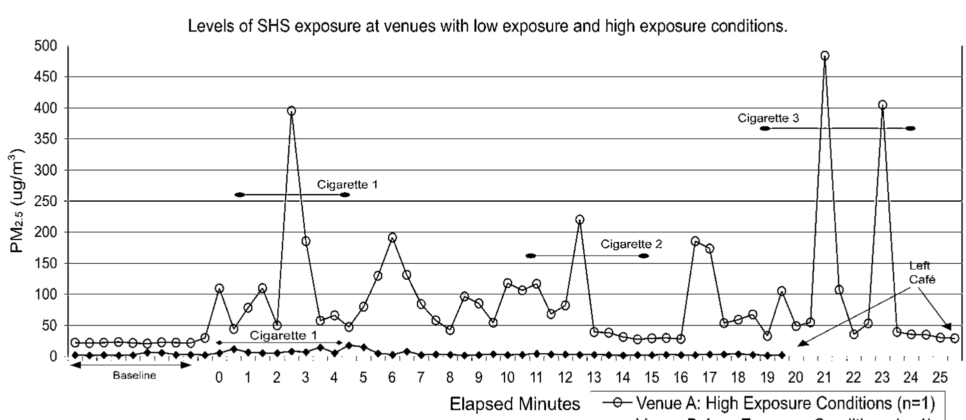

Figure 1 Levels of secondhand smoke (SHS) exposure at venues with low exposure and high exposure conditions.

levels of SHS, and this is more likely when they are seated under an overhead cover. These results suggest that exposure to SHS among patrons and staff could be reduced if overhead covers at outdoor dining areas were removed. However, overhead covering provides protection from harmful ultraviolet rays, and removal to increase ventilation would incur a consequent risk of sunburn. This is of particular concern in Australia, where levels of ultraviolet radiation and sun exposure are typically higher than those observed in North America and Europe.[33] At least two in three Australians are diagnosed with skin cancer before 70 years of age,[34] and melanoma is the most common cancer in those aged 12–24 years.[35] Therefore, the need to protect patrons and hospitality workers from unnecessary sun exposure is an imperative public health concern, and it is neither practical nor responsible to promote removal of overhead covers at outdoor dining venues. Alternative approaches to reduce SHS exposure in these venues must be considered.

Results from two small previous studies of SHS exposure in outdoor dining venues (six venues in New Zealand[36] and 20 venues in Canada[17]) show different results from those presented here, but it is evident that differences in the degree of venue enclosure may account for these findings. For example, in the Canadian study, average and maximum SHS levels were higher than those found in our study, but most of the Canadian venues had overhead cover and around half of the venues had at least 90% wall covering because of the colder climate.[17] In comparison, 71% of venues in our sample had an overhead cover, and only half of these also had substantial wall cover. Our study adds to the growing evidence about the conditions leading to significant exposure to SHS in outdoor dining areas, and we encourage further research to quantify the average and range of exposure experienced by patrons dining in venues with various levels of enclosure.

A potential limitation of our study is that we used a convenience sample, and therefore the recorded levels may not be representative of those present in outdoor dining venues across the state. However, our sampling was purposive in order to include venues with varying structural layouts. Second, we recognise that SHS is not the only source of $PM_{2.5}$ particles, with additional contributions coming from diesel cars and trucks, and cooking sources. However, we collected and controlled for baseline measurements of $PM_{2.5}$ in all analyses, thereby minimising the influence of ambient $PM_{2.5}$ sources on our results. Third, given that previous studies of outdoor SHS concentrations have demonstrated that exposure levels are particularly sensitive to wind speed and direction,[18 19] it is a limitation of this study that we did not obtain an adequate measure of wind conditions at each venue and were therefore not able to account for, or examine the effects of wind conditions on SHS exposure levels. Fourth, the limited duration of data collection (26 minutes on average) means that although the data may reflect typical exposure for patrons, we did not capture the exposure levels that would be experienced during the average shift of a hospitality employee. Another aspect of the present study worth noting is that venues were visited in late autumn, and it is possible that higher or lower average exposure levels would be observed at other times of the year.

We do not advise that the present results are used to advocate outdoor smoking restrictions at the expense of other tobacco control policies known to reduce smoking prevalence[37 38] and exposure to SHS.[13] However, given both the evidence that there is no risk-free level of SHS exposure[4] and the demonstration in this study that policies allowing smoking in semi-enclosed venues have the potential to result in unacceptable levels of exposure, such restrictions may clearly be of importance in those countries where indoor smoke-free policies and other tobacco control measures are already in place.

What this paper adds

- Despite increasing regulation of secondhand smoke (SHS) exposure in indoor public places, and growing evidence that outdoor SHS levels can be comparable to indoor levels under certain conditions, smoking continues to be unregulated in many outdoor public places. In this study we measured SHS concentrations at a large number of outdoor dining areas where smokers were present. Outdoor SHS exposure levels were highly variable, with substantial peaks in exposure occurring at some venues. Exposure to SHS was significantly increased when individuals were seated under an overhead cover, and as the number of nearby smokers increased. Greater consideration of outdoor smoking restrictions may be necessary to fully protect the health of patrons and workers at hospitality venues.

Acknowledgements The authors wish to thank the research assistants who collected the data.

Funding This study was funded by Quit Victoria, Cancer Council Victoria and the Flight Attendant Medical Research Institute. The funding bodies did not play any part in study design; in the collection, analysis and interpretation of data; in the writing of the article; or in the decision to submit the article for publication.

Competing interests All authors declare that they have NO competing interests.

Provenance and peer review Not commissioned; externally peer reviewed.

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