Exposure of children to second-hand smoke in cars

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Abstract

Objective: To investigate exposure of children to second-hand smoke (SHS) in cars under real life smoking and realistic driving conditions.

Methods: PM2.5 concentrations (particulate matter with an aerodynamic diameter below 2.5µm) were monitored as a marker for SHS in 21 car journeys using the TSI portable photometer SidePak™. Five participants (including one non-smoker) volunteered to drive their own cars and were asked to make no changes to their normal smoking behaviour. A child-sized doll was positioned in a child car seat on the back seat of each car. Monitoring took place under different traffic conditions and different ventilation conditions.

Results: Geometric mean (GM) PM2.5 concentrations during smoking journeys (65µg.m⁻³) exceeded the proposed WHO 24-hour guideline concentration for outdoor air pollution (25µg.m⁻³) and were 10 times higher than those found during non-smoking journeys (6.8µg.m⁻³). GM PM2.5 concentrations on journeys with low ventilation were 139µg.m⁻³, whereas for journeys with high ventilation the GM PM2.5 concentration was 32.5µg.m⁻³.

Conclusions: Smoking in cars produces concentrations of PM2.5 that could be classified as unhealthy, even when windows are open or ventilation is on. Based on these findings, measures to prevent smoking in cars, particularly when children are present, should be explored.

Key words: Second-hand smoke, PM2.5, passive smoking, car

Introduction

Second-hand smoke (SHS) from cigarettes is associated with respiratory symptoms, reduced lung function, asthma, lung cancer and coronary heart disease in non-smokers, often resulting in premature death (USEPA, 1992; NIH, 1999). In children, exposure to SHS increases the risk of sudden infant death syndrome (SIDS), acute respiratory infections, ear infections and asthma (DoH, 2007). Kabir et al., (2009) reported a significant increase in wheeze and instances of high fever in Irish children aged 13-14 exposed to SHS in cars. In the UK smoking in private homes and vehicles is not regulated and individuals can choose whether or not to allow smoking within the privacy of their own car or home. PM2.5 (particulate matter with an aerodynamic diameter below 2.5µm) is of particular concern because particles of this size can travel deep into the lungs and therefore pose a health hazard (Donaldson and Borm, 2007). There is no threshold value below which PM2.5 does not pose a health risk (WHO, 2005). The WHO has proposed a 24-hour guideline concentration for PM2.5 in outdoor air of 25µg.m⁻³ to protect population from health effects from outdoor air pollution (WHO, 2005).

Exposure to SHS levels in private cars under real driving conditions is not well documented. We identified only one study, Rees and Connolly (2006), that reported PM2.5 concentrations in smoking cars under real driving conditions. The authors measured PM2.5 concentrations in 43 car journeys in the US, and found a mean PM2.5 concentration of 272µg.m⁻³ when windows were closed and 51µg.m⁻³ when windows were open. Other studies have been carried out in simulated environments: Sendzik et al., (2009) observed in a controlled study where a single cigarette was smoked in each car journey, a mean PM2.5 of 844µg.m⁻³ during journeys when air conditioning was on and 223µg.m⁻³ when the smoker was holding the cigarette close to an open window. Another study in a controlled environment in New Zealand reported PM2.5 concentrations of 143µg.m⁻³ when two cigarettes were smoked with the windows half down during a period of approximately 15 minutes (Edwards and Wilson, 2006). Jones et al., (2009) found median air nicotine concentrations in smokers’ vehicles of 9.6µg.m⁻³ compared to non-detectable concentrations in non-smokers’ vehicles. The large range of concentrations found in the different studies may be a consequence of the different experimental conditions (including ventilation rate and number and type of cigarettes smoked) and possibly differences in the smoking regimes, experimental investigations where a controlled number of cigarettes are smoked may not represent the real smoking behaviour.

Methods

Participants who gave their consent were asked to behave as they normally do in relation to driving and smoking. PM2.5 was measured using a TSI photometer SidePak™ AMS10 Personal Monitor. A child-sized doll was placed on the left side of the rear seat of the volunteers’ private vehicles (passenger’s seat), as it would have been unethical to expose a child. All cars were right-handed. The inlet of the monitoring device was placed at the nose height of the doll. Participants completed a questionnaire on traffic characteristics (low, medium and high traffic density), number of cigarettes smoked during each journey, journey duration and ventilation condition and windows position.
most of the journey) and in four smoking journeys the ventilation was poor (windows closed and the ventilation system off during most of the journey). There was no information on the window positioning and ventilation system for one of the smoking journeys, and therefore this data was excluded from the dataset in the analysis of the effect of the ventilation on the PM$_{2.5}$ concentrations.

Table 1 shows the arithmetic mean (AM), GM and range of the PM$_{2.5}$ concentrations found in the smoking and non-smoking journeys.

PM$_{2.5}$ measurements generally follow a log-normal distribution and therefore the GM was used to describe the results. Differences in the log-transformed concentrations between smoking and non-smoking journeys were tested by t-tests (assuming unequal variances). The increase in PM$_{2.5}$ concentrations with increasing smoking rate (cigarettes per hour) was evaluated by least squared linear regression of the log-transformed data vs. cigarettes smoked per hour using Excel 2003. Differences in the concentrations for different variables (ventilation conditions) were evaluated using t-test and one-way repeated measures analysis of variance (ANOVA).

Results

In total, PM$_{2.5}$ measurements were carried out during 21 journeys. The number of cigarettes smoked per journey ranged from 0 to 3; during 15 of the 21 journeys smoking occurred in the car. The duration of the journeys ranged from 10 to 80 minutes with an average of 46 minutes. During six smoking journeys, the ventilation was high (windows were open and the ventilation system on during at least part of the journey) although it is not known the degree to which these were open (fully or partially). During four smoking journeys the ventilation was medium (windows closed and ventilation on during most of the journey) and in four smoking journeys the ventilation was poor (windows closed and the ventilation system off during most of the journey). There was no information on the window positioning and ventilation system for one of the smoking journeys, and therefore this data was excluded from the dataset in the analysis of the effect of the ventilation on the PM$_{2.5}$ concentrations.

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PM$_{2.5}$ measurements in smoking journeys appeared to be higher when the ventilation was poor (GM=65 µg m$^{-3}$, n=6), compared to journeys where the ventilation was medium (GM=57.2 µg m$^{-3}$, n=4) or high (GM=32.5 µg m$^{-3}$, n=4); despite the smoking rate, were similar for journeys with high and medium ventilation (2.0 and 1.75 cigarettes/hour respectively). These differences were statistically significant at the 0.01 level (ANOVA test).

The SidePak™ uses a laser photometer to detect particles in real time. The device was fitted with a selective inlet to collect particles with a median aerodynamic diameter corresponding to the definition of PM$_{2.5}$ aerosol. Airflow rates were set up to 1.7 l m$^{-1}$. Measurements were recorded every 1 minute and the average concentration was calculated for the duration of the journey. A calibration factor of 0.295 was applied to the results generated by the SidePak™ to correct for the properties of SHS particles (Kabir et al., 2009; Jones et al., 2009).

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There was no statistically significant difference in PM$_{2.5}$ concentrations between light, medium and high traffic conditions ($p>0.05$) for non-smoking and smoking journeys.

Figure 2 shows a scatter plot and relationship between the logarithm transformed PM$_{2.5}$ concentrations and the rate of cigarettes smoked during the survey (number of cigarettes smoked per hour).

There was a clear trend for higher PM$_{2.5}$ concentrations with increasing smoking rate. After removing an outlier, which deviated from the linear trend, 56% of the variance in the log-transformed PM$_{2.5}$ concentrations...
was explained by the rate of cigarettes smoked in the car (Figure 2). Smoking one cigarette per hour resulted in PM$_{2.5}$ concentrations of 25µgm$^{-3}$.

Opening windows and switching on the ventilation system resulted in lower concentrations (GM=32.5µgm$^{-3}$, n=4) than having the windows closed or ventilation system off (GM=139µgm$^{-3}$, n=6).

**Discussion**

**Main findings of the study**

This study examined the levels of PM$_{2.5}$ as a marker for SHS during car journeys. The PM$_{2.5}$ concentrations found during smoking journeys greatly exceeded the WHO recommended daily exposure limit of 25µgm$^{-3}$ for outdoors air (WHO, 2005). Although PM$_{2.5}$ levels were reduced when windows were opened or ventilation switched on, these levels still generally exceeded the proposed EU limit value. PM$_{2.5}$ levels increased with increasing smoking rate. Although we compared the PM$_{2.5}$ concentrations with outdoor standards (since there is no current standard for indoor environments) it should be considered that these may underestimate the actual hazard of PM$_{2.5}$ from SHS. As SHS contains high concentrations of carcinogenic compounds, is likely to be more hazardous than outdoor particles (Klepeis et al., 2007). On the other hand, the duration of exposure to SHS in cars will be much less than 24 hours per day.

**Limitations of this study**

There are some limitations that should be considered when interpreting the results reported in the current study. Results were available only from a limited number of journeys and more data are required to confirm these results and investigate the impact of different smoking behaviours and window and ventilation settings on the SHS levels in the car. In addition, it is considered that the main scenario for children exposure to SHS is at home (Rees and Connolly, 2006). Therefore, the SHS exposure experienced in cars is likely to represent only a fraction of their total personal exposure.

**Possible policy implications**

PM$_{2.5}$ concentrations in journeys where smoking occurred exceeded the WHO guideline value for 24-hour for outdoor air pollution (25µgm$^{-3}$), even in journeys with windows open or ventilation system switched on (32.5 µgm$^{-3}$). Taking into account that there is no threshold value below which PM$_{2.5}$ does not pose a health risk and that PM$_{2.5}$ from SHS is likely to be more hazardous than outdoor exposures, measures to prevent smoking in cars, particularly when children are present, should be explored. The public should be informed about the potential risk that smoking in cars has for children.

**Conclusion**

Real life smoking in cars under real driving conditions produce concentrations of PM$_{2.5}$ that could be classified as unhealthy, even when windows are open or ventilation is on.

**References**


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US Environmental Protection Agency USEPA (1992). Respiratory health effects of passive smoking (also known as exposure to second-hand smoke or environmental tobacco smoke ETS) Office of Health and Environmental Assessment Office of Research and Development U.S. Environmental Protection Agency Washington, D.C.
