Study of air pollution on Lower Hutt city streets: Smoking associated with worse air quality than road traffic

Draft report

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ABSTRACT

Introduction: To address the paucity of research around smokefree streets, we aimed to: (i) refine existing data collection methods; (ii) expand on the meagre previous research in this area; and (iii) compare results by differing size of urban centre.

Methods: We refined established methods and used a solo observer method to simultaneously observe smoking and measure fine particulate levels ($PM_{2.5}$) on a route of shopping streets in central Lower Hutt, New Zealand.

Results: For 33.6 hours of measurement, mean fine particulate levels were 1.7 times higher when smoking was observed than when it was not (7.9 vs 4.8 µg/m^3; p=0.0001).

Conclusions: Smoking appeared to be a substantive contributor to fine particulate air pollution, when compared to levels adjacent to road traffic.

Keywords (MeSH terms):

- Environmental Monitoring/methods
- New Zealand
- Risk Assessment
- Smoking/legislation & jurisprudence
- Tobacco Smoke Pollution/adverse effects
- Urban Health

INTRODUCTION

Smokefree city streets are a frontier domain for denormalising smoking and reducing nuisance and health concerns for non-smokers (American Nonsmokers' Rights Foundation, 2011; Ueda et al., 2011). These policies are also attracting attention from urban authorities who may be interested in ‘healthy’ city branding, and reducing litter and fire costs (Schneider et al., 2011). In particular, tobacco smoke pollution (TSP) has been found to contribute to outdoor $PM_{2.5}$ levels from work in Canada;(Kennedy et al., 2007) the USA;(Klepeis et al., 2007) Australia (in Perth,(Stafford et al., 2010) and in Melbourne;(Cameron et al., 2010)) and New Zealand (Wilson et al., 2011). Further work in Canada found that smoking within nine metres of building entrances significantly contributes to raised $PM_{2.5}$ levels (Kaufman et al., 2011). Previous work in Wellington City, New Zealand observed smoking and measured air quality in central Wellington (Parry et al., 2011). In that study, simultaneous observation of smoking behaviour and measurement of air quality were conducted for 3.4 hours.

To add to the very limited work on observing smoking and corresponding fine particulate levels on shopping streets,(Parry et al., 2011) we aimed to: (i) refine existing methods to simultaneously observe smoking and air quality measurements with a single observer; (ii) conduct observations and air quality measurements for a much longer period than in the central Wellington study; and (iii) compare our results (from streets in a small urban centre) with previous data from central Wellington (Parry et al., 2011).

Compared to Wellington City, Lower Hutt has both a lower population (102,700 vs 197,000 people) and population density (272 vs 682 people per km^2). The Lower Hutt shopping area also appears to have only low-rise buildings, less foot traffic and a lower proportion of businesses with outdoor eating areas, compared to central Wellington, which also has a much higher daytime population due to office workers. Wellington and Lower Hutt both have relatively low background air pollution levels (Greater Wellington Regional Council, 2010).

METHODS

To ensure our methods were feasible, a trial protocol was developed and tested. Using the final protocol, smoking by people outdoors on the street was observed and fine particulate levels ($PM_{2.5}$) were measured while:

(a) Walking along a standard route of shopping streets in central Lower Hutt 2.4km long (*n*=35 occasions, averaging 56 minutes per sampling period, at 2-hour intervals (starting from 8.30 am to 6.30 pm) on Tuesdays, Fridays and Saturdays between 9 April and 14 May 2011 (route map: http://goo.gl/maps/lXyj).

For each sampling period in Lower Hutt, a single observer (VP) walked one length of the route on one side of the street, then upon reaching the end of the route, switched to the opposite side of the street and walked the return length. The observer walked in the direction of road traffic flow (of the nearest lane) and counted only active smokers that were passed. The observation area included up to the middle of the road, so that each sampling period would cover the total road and pavement area. Data were collected on all people who were smoking and who were outside of buildings or vehicles.

(b) At purposeful settings along this route (*n*=5 occasions, averaging 12 minutes per sampling period);
(c) Adjacent to rush-hour traffic along this route (*n*=1 occasion for 30 minutes; (route map: http://goo.gl/maps/S4iF)) on Saturday 7 May 2011.

Observation: Active smoking was defined as someone holding a lit cigarette/cigar/pipe in their hand/mouth. Wind speed measurements were taken at predetermined locations using a handheld monitor when either walking along the Lower Hutt route or adjacent to rush-hour traffic.

When smoker(s) were observed, data were recorded in real-time on the number of smokers observed and the approximate proximity of smokers (from the observer to the nearest metre). Each smoker observed was counted separately in establishing totals (although it is possible that some may have been re-encountered during the walking).

Fine particulate measurement: Established methods(Parry et al., 2011) were used to measure fine particulate levels ($PM_{2.5}$; ie, particles ≤ 2.5 mm in diameter) related to TSP using a portable real-time airborne particle monitor (the TSI SidePak AM510 Personal Aerosol Monitor; TSI Inc., St Paul, MN). The device was set to record mean $PM_{2.5}$ levels over 30-second intervals.

To provide background fine particulate levels, data collected at purposeful settings included periods of time away from smokers (lasting ~3-5 minutes before and after seeing smokers). While adjacent to rush-hour traffic, fine particulate levels were measured and traffic levels counted (using a mechanical counter) from both sides of the road for equal periods of time.

Data recording: A new refinement was that all data were entered into a personal digital assistant (PDA; Apple iPod touch; Apple Inc., Cupertino, CA) using a predefined shorthand. To ensure the automatically assigned timestamp data between the PDA and air monitor were comparable, the clocks of both devices were routinely checked prior to data collection.

Data were retrieved from the PDA and air monitor using the software Mail (Apple Inc., Cupertino, CA) and TrakPro (TSI Inc., St Paul, MN) respectively and transferred into a Microsoft Excel database. An array formula was used to automatically align the data collected from the PDA and air monitor based on their respective timestamps. The aligned data were then manually checked to ensure the alignment process was correct. Data were analysed using Excel, OpenEpi (Emory University) and Stata (StataCorp., College Station, TX).

Ethical approval was granted via the University of Otago ethics approval process.

RESULTS

The revised methods used were feasible and are likely to produce more robust results than previous methods. In particular, it was possible for a single to observer to collect data on observed smoking and measure fine particulate levels. A total of 284 smokers were observed in 32.7 hours of walking along the route of shopping streets in central Lower Hutt, which is equivalent to 1.5 observed smokers every ten minutes (see Table 1).

Particulate levels: The measurement of fine particulate levels had high face validity, with elevated $PM_{2.5}$ levels when people were observed smoking. While walking along the route of shopping streets in central Lower Hutt, mean $PM_{2.5}$ levels were 1.7 times higher in the collective 2.2 hours when smoking was observed than when it was not (7.9 vs 4.8 µg/m^3, Kruskal–Wallis [KW] test for two groups, p=0.0001, see Table 1). The mean distance of observed smokers (from the observer) was 2.6 metres. The mean wind speed was 3.3 kmph (n=252 measurements; range=0.3–13.6 kmph).

For purposeful sampling alone (excluding rush-hour traffic measurements), mean $PM_{2.5}$ levels were 4.5 times higher when smoking was observed then when it was not (25.1 vs 5.6 µg/m^3, KW test, p=0.055). While standing next to one smoker at a bus stop (which only had a high shop overhang), mean $PM_{2.5}$ levels were 76.5 µg/m^3 with a peak level of 128.0 µg/m^3 (see Table 1).

For *all* sampling (ie, all walkthrough sampling and purposeful sampling except that adjacent to rush-hour traffic), mean $PM_{2.5}$ levels were almost two times higher when smoking was observed than when it was not (9.3 vs 4.8 µg/m^3 , KW test, p=0.0001). Similarly, for purposeful sampling adjacent to rush-hour traffic in Lower Hutt (also 9.3 vs 4.8 µg/m^3, KW test, p=0.0001). A dose-response pattern between proximity to people smoking and $PM_{2.5}$ levels was also apparent. Mean $PM_{2.5}$ levels when smokers were approximately 1, 2 and 3 or more metres from the observer were 10.5, 8.3 and 7.3 µg/m^3 respectively (KW test, p=0.1293). Mean $PM_{2.5}$ levels for multiple smokers were significantly higher than when only one smoker (9.6 vs 9.2 µg/m^3, KW test, p=0.0204) (see Table 2 and Figure 1).

DISCUSSION

Our results confirm that fine particulate levels significantly increase when smoking is observed, over a much larger time period than for previous work in central

Wellington, and when passing only 25% of the smokers per hour found in that previous work.

Observed smoking and fine particulate levels

Fine particulate levels when smokers were observed were lower in Lower Hutt than previous research in central Wellington (for all observations, purposeful and when walking: 9.3 vs 14.2 $\mu g/m^3$; and only when walking: 7.9 vs 9.3 $\mu g/m^3$) (Parry et al., 2011). This is probably because smoking was observed more frequently in central Wellington (7 vs 1.5 smokers every ten minutes). Alternately, pavements in central Wellington may be more sheltered by tall buildings, and more 'enclosed' compared to Lower Hutt (eg, due to lower overhanging roofs and/or higher pedestrian foot traffic levels, which would effectively reduce the 'open space' for cigarette smoke to disperse). Nevertheless, wind speeds are generally higher in central Wellington than Lower Hutt (means of measurements at official observation points during the observation dates; 18.1 vs 8.3 kmph respectively) (Personal email from Ross Marsden, New Zealand MetService, 8 September 2011).

The background $PM_{2.5}$ level when smokers were *not* observed was similar to being adjacent to rush-hour traffic in Lower Hutt and in central Wellington,(Parry et al., 2011) (4.8 $\mu g/m^3$ and 5.0 $\mu g/m^3$ respectively). However, it is higher than mean levels measured in other outdoor settings in the Wellington area such as parks and sports grounds,(Wilson et al., 2011) (2 $\mu g/m^3$) or in central Wellington during periods with 'quiet' traffic,(Parry et al., 2011) (2.9 $\mu g/m^3$). This would suggest that the proportionate effect of smoking on producing fine particulate levels on shopping streets *without* traffic pollution would be even greater than indicated by our study.

Our other findings of very high peak $PM_{2.5}$ levels, and dose-response patterns for particulates for both the number and proximity of smokers, are consistent with previous research in central Wellington,(Parry et al., 2011) and we have replicated them in the setting of a smaller and less densely populated central city area. These results have implications for protecting public health and urban policy planning, given that pedestrians are largely confined to street pavements.

Quality of the methods

Our refinements to an established protocol,(Parry et al., 2011) were to: (i) record observational data into a PDA; (ii) align observational and fine particulate data automatically; and (iii) simultaneously observe smoking and measure TSP levels for *all* observations of smoking in city streets with a single observer. These refinements which aimed to maximise data quality are likely to produce more robust results (than previous methods).

To represent smoking throughout the course of a week, data were systematically collected on a standardised route on Tuesdays, Fridays and Saturdays. The density of pedestrians was such that identifying active smokers was not problematic. The amount of data collected on observed smoking in the streets and corresponding fine particulate levels is ten times greater than the largest previous study,(Parry et al., 2011) (33.6 vs 3.4 hours), allowing for much greater statistical precision.

However, data were collected in just one city at specific times over five weeks during one season of the year (autumn). Thus our results may not be fully representative of smoking in Lower Hutt City streets throughout the year (and will not be particularly generalisable to other New Zealand cities). We also did not measure the *prevalence* of smoking in the street (with all observed people as the denominator), as this is problematic when the moving observer method is used and the observation area is constantly changing.

Further research

This type of study repeated over time in other outdoor settings (eg, parks, playgrounds, bus stops) locally, nationally and internationally can provide objective comparisons of the extent of smoking, compliance with smokefree laws and TSP levels. Possible refinements include collecting smoking prevalence data and other contextual variables (such as pedestrian foot traffic levels). Such data may help explain differences in TSP on shopping streets between small and large cities.

Health sector promotion of intervention studies and systematic evaluation studies would allow the effects of policy changes to be examined as the number and implementation levels of smokefree outdoor area policies increase over time.

Policy implications

Urban policy could protect pedestrians from smoking, especially those confined to pavements, and those around outdoor seating (eg, for cafés). Such smokefree policies for streets could also help limit the drift of TSP indoors (Wilson et al., 2011). There are some precedents for smokefree street policies, (Ueda et al., 2011)(Broder J, 2006)(Meagher, 2011)(San Diego Union-Tribune, 2007) (The Tribune, 2010)(Wang, 2008)(Ogilvie, 2010) which could help to further denormalise smoking, and reduce litter and environmental damage (Thomson et al., 2008; Slaughter et al., 2011).

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