

Space-time analysis of unhealthy food advertising: New Zealand children's exposure and health policy options

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Summary

Reducing children's exposure to unhealthy food advertising is an accepted strategy to end childhood obesity. This study aimed to (i) measure children's space-time exposures to unhealthy food advertising in public outdoor spaces, using GPS and wearable cameras; and (ii) test effectiveness of banning options. We compiled data (collected July 2014–June 2015) on 138 12-year-old children in Wellington, New Zealand, using wearable cameras and GPS devices worn over 4 days. In 2017–18, we linked 59 150 images taken in public outdoor spaces to GPS data. Of these, 1631 contained unhealthy food advertising exposures, defined as $\geq 50\%$ of an advertisement observed in each image. We examined spatial patterns using kernel density mapping and graphed space-time trends. We interpolated a kriged exposure rate across Wellington to estimate exposure reductions for potential bans. Children were exposed to 7.4 (95% CI 7.0–7.8) unhealthy food advertisements/hour spent in outdoor public spaces. Exposures occurred in shopping centres, residential areas and sports facilities, commonly involving fast food, sugary drinks and ice cream. Peak exposure times were weekend afternoons/evenings and weekdays before/after school. In Wellington, we estimated that banning such advertising within 400 m of playgrounds would yield a 33% reduction in exposure, followed by in residential areas (27%), within 400 m of schools (25%), and 50% for a ban combining all above. This work documents the extent of children's exposure to unhealthy food advertising and the potential impact of bans. Given the ubiquity of advertising in public spaces, this New Zealand research offers innovative methods and findings likely relevant in other jurisdictions.

Key words: spatio-temporal analyses, unhealthy food advertising, obesity, children

INTRODUCTION

Childhood obesity has reached epidemic proportions globally resulting in significant health risks throughout life (Ng *et al.*, 2014). To end childhood obesity, the

World Health Organization has called for global action to reduce the impact of food and beverage advertising to children (Seventieth World Health Assembly, 2017). Outdoor advertising in public spaces is an important

medium contributing to children's exposure to unhealthy food and beverage advertising (Pasch and Poulos, 2013). Evidence suggests outdoor advertising is located near places children frequent such as schools, early childhood education centres, main streets, restaurants and sports and recreation venues (Maher et al., 2005; Kelly et al., 2008; Adams et al., 2011; Gebauer and Laska, 2011; Powell et al., 2012; Settle et al., 2014).

Global action to restrict unhealthy outdoor food advertising has been limited. For example, the Green Food Zones in South Korea banned the sale and advertisement of unhealthy food within a 200 m radius of schools (Bae et al., 2012). In 2013, Peru introduced comprehensive restriction of the advertising of energy-dense nutrient poor foods and drinks to children under 16 years of age via all marketing media (Balcázar, 2015). From 2019, unhealthy food advertising is banned on the London tube and bus network (Mayor of London, 2018).

Currently, most research has focused on children's space-time exposures to unhealthy food outlets (Sadler et al., 2016), leaving little known about direct and objective measured exposures to unhealthy food advertising. The application of space-time analysis of advertising exposures across, for example, public spaces in a city could help inform interventions to ban unhealthy food advertising. Such analyses could identify specific space and time hotspots of unhealthy food advertising exposures and inform targeted areas for intervention and policy. Therefore, this study aimed to: (i) measure and visualize children's space and time exposures to unhealthy food advertising in public, outdoor spaces, using GPS and wearable camera technology; and (ii) test potential reduction of exposure by proposing banning unhealthy food advertising near schools, playgrounds, or in residential areas. This study builds on previous research which quantified children's exposure to all forms of food marketing (e.g. product packaging) (Signal et al., 2017b). In this study, a detailed analysis was undertaken of where and when exposure to unhealthy food marketing occurs in public outdoor spaces (e.g. signs) as these exposures may be particularly amenable to advertising bans. Doing this allowed, for the first time, modelling of potential policy options to ban such marketing in particular places and times across a city.

MATERIALS

Study design and participants

This study utilizes data collected for a larger study, Kids'Cam, a cross-sectional observational study conducted in the Wellington region of New Zealand (Wellington City, Porirua City, Lower Hutt City and

Upper Hutt City) between July 2014 and June 2015. A total of 168 randomly selected students from 16 randomly selected schools participated. The sample was intentionally stratified by ethnicity and school socio-economic status (Signal et al., 2017b). Participants were instructed to wear a wearable camera and a GPS device on lanyards around their neck for their entire day for four consecutive days (Thursday–Sunday). The wearable cameras automatically captured a 136-degree image of the children's surroundings every 7 s over 4 days ($n = 1.3$ million images). The GPS devices recorded children's latitude and longitude coordinates every 5 s ($n = 3$ million coordinates). Further details about the Kids'Cam study design can be found elsewhere (Signal et al., 2017a,b). This project used a subset of Kids'Cam participants ($n = 138$) who had outdoor advertising data that could be linked to GPS data ($n = 30$ excluded).

Measures

All images were manually coded for food advertising exposure via content analysis (Rose, 2012). Experienced coders achieved 90% concurrence with model answers on a test set of 115 images before coding commenced. Advertising was defined as 'any form of commercial communication or message that is designed to, or has the effect of, increasing recognition, appeal and/or consumption of particular products and services' (Bae et al., 2012). An exposure was determined if 50% or more of an advertisement could be clearly coded in an image or series of images. An exposure was considered to have ended when 30 s had elapsed since the last recorded code. Food product categories were further classed as: core (nutrient-rich foods recommended to be marketed to children—e.g. fruits and vegetables) versus non-core (not recommended) based on the WHO Regional Office for Europe Nutrient Profiling Model (World Health Organization Regional Office for Europe, 2015), a model developed specifically for identifying foods that should not be marketed to children (Lobstein et al., 2015). More information on the coding protocol is published elsewhere (Signal et al., 2017b). Non-core foods are referred to as unhealthy foods throughout the paper. They included sugary drinks, fast food, confectionery, snack foods, ice cream, cookies/cakes/pastries and unhealthy milk and cereal products (World Health Organization Regional Office for Europe, 2015).

GPS data were linked to image codes which occurred in outdoor public spaces based on timestamps rounded to the nearest 5 s. Cleaning and imputation methods for missing data were applied to GPS data to correct noise caused by satellite communication obstruction or

compensate for missing data due to lost signal or power, given a set of rules (Signal *et al.*, 2017b). Thus, the final analytical dataset contained 59 150 images from 138 children. Among these, 1631 contained an unhealthy food advertising exposure, among 88 of the 138 children included in our analyses.

All coordinates for all included images were plotted by weekday versus weekend using ArcMap 10.5 (ESRI, Redlands, CA, USA). The average nearest neighbour ratio, which is the observed average distance between each point and its nearest neighbour over the expected mean distance for the points given in a random pattern, was used to measure the degree of clustering of exposures. Next, kernel density estimation maps [similar to a probability density function] were created to identify areas of high to low outdoor unhealthy food exposure density across the study area, where each raster [pixel] cell represents the density of exposures among the nearest cells (50 m cell size). In this way, cell values peaked at the location of the exposure and gradually decreased to zero until the search radius distance from the point was reached (2 km).

To view exposures in space-time cube diagrams, times of exposures were rounded to the nearest 5 s. Then, all exposures for the 4-day observation period were combined into one virtual day to examine temporal trends by time of day. Points were then plotted in ArcScene 10.5 (ESRI, Redlands, CA, USA).

Evaluation of policy options to reduce exposures—a Wellington City case study

Since Wellington City is the most populated area in the study region, we used it to test potential policy options. To create a smoothed surface of estimated exposure rates across the city, we first defined the food advertising exposure rate as the ratio of the number of outdoor unhealthy food advertising exposures to the total number of outdoor images within a 100 m × 100 m unit area, indicating the chance of being exposed to unhealthy food marking when a child visited that location. A total of 26 830 images/coordinates and 762 unhealthy food advertising exposures were used to calculate exposure rates for the grid. Grid cells that did not contain any images/coordinates were excluded from analyses. To account for small numbers, we smoothed the data using an empirical Bayes estimation (Shortridge *et al.*, 2014). Calculation of the estimated exposure rates was conducted in R v.3.4.3 (R Core Team, 2017), using the equations in the Supplementary.

Next, the smoothed exposure rates for the raster grid were extracted to grid centroids [centre of each pixel].

We used these point estimates to calculate global spatial autocorrelation using Moran's I Index, which is a measure of the degree to which locations closer to one another are more similar or more diverse for a given attribute (i.e. unhealthy food exposures). Then, we used ordinary kriging to estimate exposure to unhealthy food over a continuous 100 m × 100 m surface covering Wellington City given the known exposures from our linked image and GPS data, using ArcMap 10.5 (specifying at least 2 points within 540.89 search radius).

We used this smoothed, interpolated risk surface to estimate reduction of exposure for the following scenarios banning outdoor unhealthy food advertising: (i) near schools; (ii) around public playgrounds; (iii) in residential areas and (iv) in all areas aforementioned. Locations of all primary and secondary schools ($n = 85$) in Wellington were compiled using a 2008 New Zealand school dataset. Locations of playgrounds were compiled from Wellington City Council Open Data Portal ($n = 113$). Wellington City Council District Plan Zones were used to extract residential areas, also from the Wellington City Council Open Data Portal (<http://data-wcc.opendata.arcgis.com/datasets/>).

To estimate the effect of interventions, we used two different geographic scales (200 and 400 m buffers), similar to existing unhealthy food banning policies in other countries (Bae *et al.*, 2012; Mayor of London, 2017). For all interventions, we assumed that bans would result in zero exposures to outdoor unhealthy food advertising in the public spaces for each intervention we evaluated. A child's estimated exposure rate reduction due to the school or playground interventions is defined as the ratio of total exposure rate in the banned area over the total exposure rate of the entire Wellington City. The numerator for the exposure rate reduction for each of the banned areas was calculated as the sum of cell values from the kriged surface that lie within the 200 m or 400 m buffer. To estimate effects of bans in residential areas, we dissolved 1288 residential polygons into one multipart feature. A combined banned area was created by merging 400 m school buffers, 400 m playground buffers and the dissolved residential polygon into one single geographic feature. We calculated descriptive statistics of exposure rates and average predicted semi-variance in all these proposed banned areas.

RESULTS

Among 138 children included in our analyses, the majority were New Zealand European (40%) followed by Māori (35%) and Pacific children (25%) (Table 1).

Table 1: Sociodemographic and school characteristics of participants ($n = 138$)

Characteristic	Subgroup	n (%)
Ethnicity	NZ European	55 (40)
	Māori	49 (35)
	Pacific	34 (25)
Age (years) ^a	11	12 (9)
	12	100 (75)
	13	21 (16)
	14	1 (0)
Gender	Female	72 (52)
	Male	66 (48)
BMI ^b	Underweight	8 (6)
	Healthy	70 (51)
	Overweight	39 (28)
	Obese	20 (15)
School deprivation decile ^c	Low (1–3)	44 (32)
	Medium (4–7)	51 (37)
	High (8–10)	43 (31)

^aAge missing for four participants (questionnaire not completed).

^bBMI missing for one participant as child declined measurement.

^cHigh decile indicates least deprived students in the school, on average.

Most participants were aged 12 years, and there were approximately the same numbers of males and females. Due to the sampling design, there was approximately the same number of participating schools from decile groups.

Overall, children were exposed to a mean of 8.3 (95% CI 7.9–8.7) food advertisements for every hour they spent in outdoor public areas. Of these, 7.4 (95% CI 7.0–7.8) or 89.2% were for unhealthy and 0.8 (95% CI 0.7–1.0) or 9.6% were for healthy food products. Figure 1 shows the kernel density of unhealthy food advertising exposure where darker shades indicate the highest density of exposures and lighter shades indicate the lowest. After examining the attributes of image codes from high density exposure areas, these hot spots corresponded with locations of shopping centres, highly populated residential areas, as well as public transportation or sport facilities. Shop fronts and streets, particularly main streets, were the most common settings where unhealthy food advertising exposure occurred. Public transport facilities, fresh food markets and service station forecourts were the least common settings for such exposure. Children were exposed most commonly to advertisements for fast food, sugary drinks, ice cream, cookies and confectionery. Only 11 children were exposed to unhealthy food advertising in public transport facilities, and only six children were exposed to unhealthy food advertising in fresh food markets.

We observed generally similar spatial distributions in exposure to unhealthy food advertising in outdoor spaces by weekday ($n = 832$) versus weekend ($n = 799$, mostly in Wellington City) (see [Supplementary Figure S1](#)). Based on visual inspection, exposure sites during weekends covered slightly more of the study area, compared to weekdays. However, the average nearest neighbour distance ratio of weekends (ratio = 0.05, $z = -51.56$, $p < 0.0001$) was slightly smaller than that of weekdays (ratio = 0.07, $z = -51.52$, $p < 0.0001$) indicating a more ‘clustered’ point pattern. Here, the ratios are the observed mean distance over the expected mean distance and the z -scores and p -values indicate whether or not to accept or reject a null hypothesis of a random spatial pattern. For both weekends and weekdays, the results indicate significant clustering. When examining space-time cubes, weekday exposures (Figure 2, circles) frequently occurred during times of travel to/from school (peak hours 7:00–8:30 am and 3:00–4:00 pm). During weekends, exposures often occurred in the afternoon (Figure 2, triangles).

Figure 3 shows the Bayesian estimation smoothed exposure rates across Wellington (see [Supplementary](#) for descriptive statistics on this surface) and the locations of the playgrounds (Figure 3A), schools (Figure 3B), residential areas (Figure 3C) and a combined ban that integrates bans around playgrounds, schools and in residential area (Figure 3D). The Global Moran’s I Index of the Bayesian estimated rate was 0.072 ($p < 0.0001$, $Z = 12.8725$) indicating the presence of positive, significant yet weak spatial autocorrelation.

Based on the four scenarios in Figure 3A–D, the resulting estimated reduction in exposure rates for the proposed bans are shown under maps in the figure. Among all proposed banning scenarios, the average exposure rate ranged between 0.042 and 0.051. This indicated that, for example, within 200 m of schools in Wellington City, there is about a 5% chance that child would experience an outdoor unhealthy food advertising exposure when visiting that area. Banning outdoor advertising of unhealthy foods within 400 m of playgrounds would reduce estimated exposure by 33%, followed by residential areas (27%), and 400 m of schools (25%). Banning advertising in residential areas and within 400 m of both schools and playgrounds would reduce estimated exposure by 50%.

DISCUSSION

Children in this study were exposed to 7.4 unhealthy food advertisements for every hour they spent in outdoor settings, nine times more than healthy food

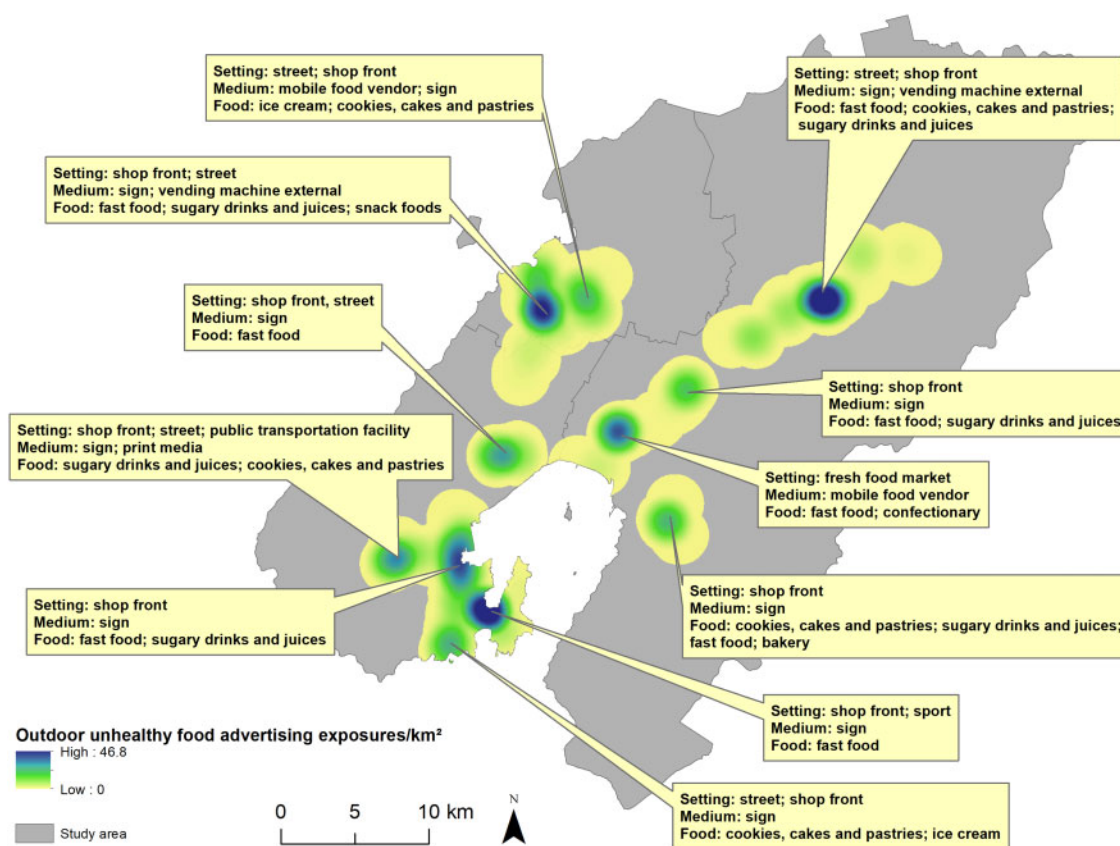


Fig. 1: Kernel density map of unhealthy food advertising exposures in public spaces, with example image coding for setting, advertising medium at high density locations.

advertisements (0.8). High density exposure areas were shopping centres, residential areas, public transportation and sport facilities. Shop fronts and streets, particularly main streets, were the most common settings where unhealthy food advertising exposure occurred. Children were exposed most commonly to advertisements for fast food, sugary drinks, ice cream, cookies and confectionery.

We observed similar spatial patterns in exposure during weekdays and weekends. However, the temporal patterns were different whereby weekday times before and after school (7–8:30 am and 3–4 pm) and weekend afternoons and evenings were times of peak exposure. This is likely due to children travelling to and from school and engaging in outdoor recreation activities during these time periods. The policy options explored here could be extended to include a temporal dimension by, for example, restricting sandwich board or other moveable sign advertising of unhealthy foods during these peak exposure times.

The high rate of children's exposure to unhealthy outdoor food advertising in this study is concerning as systematic review evidence suggests that exposure to food advertising increases liking for and acceptability of the advertised food products (Cairns *et al.*, 2009, 2013). Furthermore, there is strong evidence that food advertising and promotion influences children's food purchases and their purchase requests (Cairns *et al.*, 2013). This is particularly concerning when a major source of outdoor advertising is on shop fronts, likely places where children can purchase the unhealthy advertised products.

These findings highlight that children are exposed to food advertising in everyday settings such as shopping areas and the street, places not typically conceptualized as child spaces (Rasmussen, 2004; Carroll *et al.*, 2015b). The findings are consistent with previous research on children's use and experience of public spaces. That research reports that children often spend time in the street walking to and from school (or between activities), and commonly spend a large proportion of their

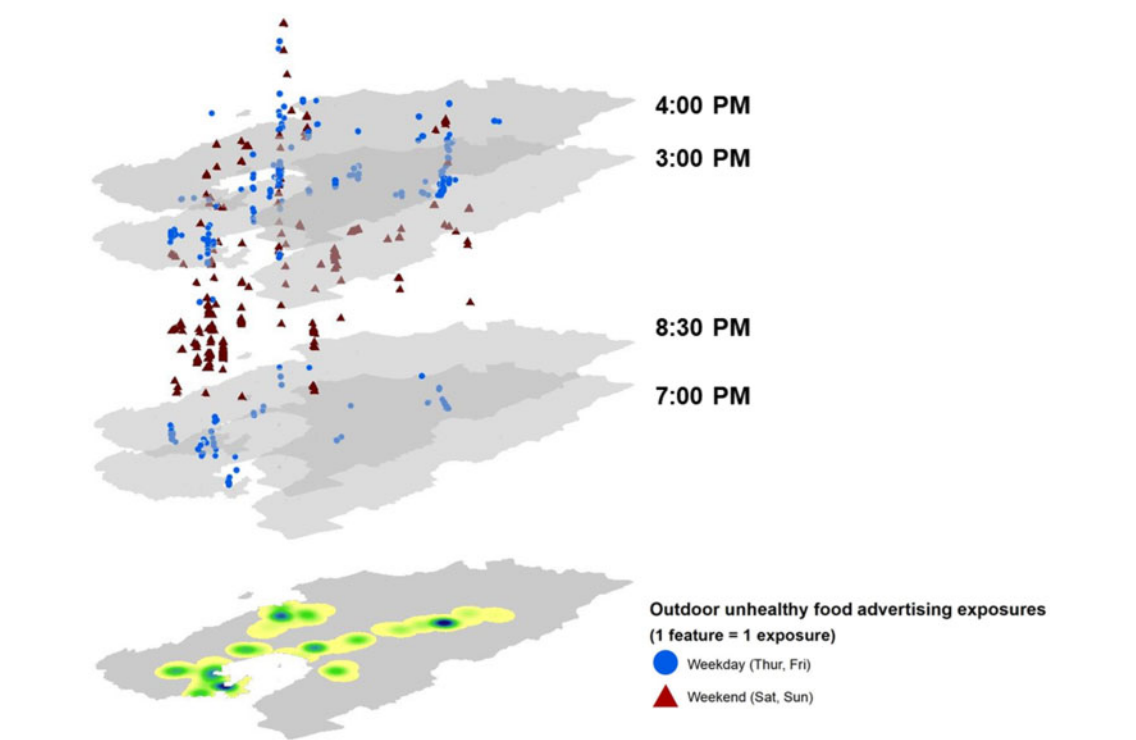


Fig. 2: Space-time cube of outdoor unhealthy food advertising exposure locations by day and time of day.

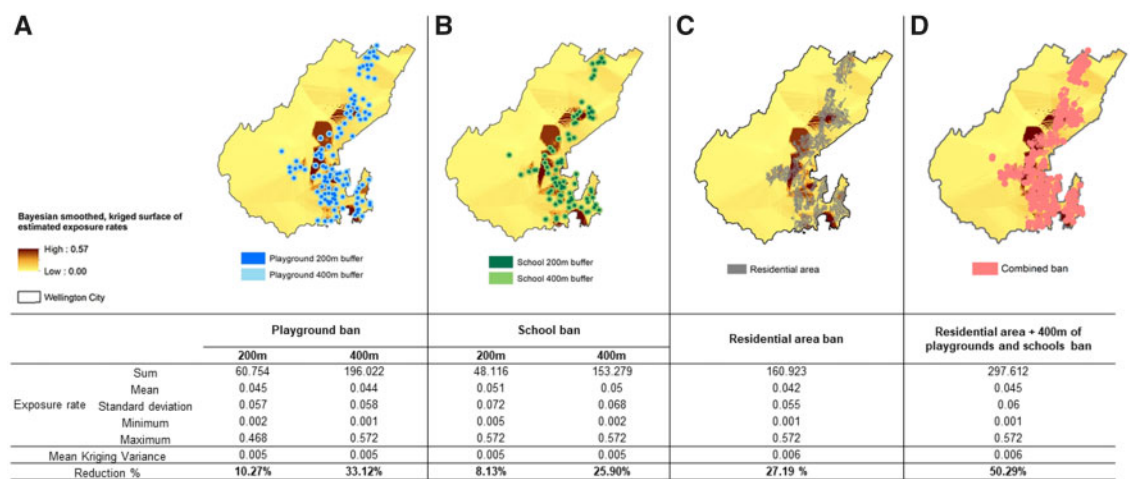


Fig. 3: Outdoor unhealthy food advertising banning scenarios and estimated exposure reduction rate using a Bayesian smoothed, kriged surface of estimated exposure rates in Wellington City, for bans (A) near playgrounds; (B) near schools; (C) in residential areas and (D) a combined ban. In our kriged interpolation, a predicted semi-variance (i.e. kriging variance) raster was created, where each cell has a predicted semi-variance value. Assuming the kriging errors are normally distributed, there is a 95.5% probability that the actual z-value for the cell is the predicted raster value $\pm$ two times the square root of the kriging variance for the cell. In this figure, we reported the average kriging variance for all cells. Actual variance varies from cell to cell.

leisure time playing in the street, and visiting shopping complexes and retail outlets (Elsley, 2004; Freeman, 2010; Carroll *et al.*, 2015a,b; Chambers *et al.*, 2017).

There have been repeated calls from the WHO for the restriction of food marketing to children in settings identified as ‘children’s places’ (such as school and other institutions designed for their use) (World Health Organization, 2012, 2016, 2017). However, public spaces, including streets and the public areas surrounding shop fronts are noticeably absent from conversations about places where food marketing should be restricted. The results of this research suggest a broader range of policy options needs to be considered, as we have done here.

Our estimates of reduction of exposure for the four scenarios banning outdoor unhealthy food advertising (near schools; around public playgrounds; in residential areas and all three areas together) indicated that banning advertising in residential areas and within 400 m of both schools and playgrounds would reduce children’s exposure to unhealthy outdoor food advertising by an estimated 50%. Banning unhealthy food advertising in larger zones could further reduce estimated exposure. Despite highly populated residential areas containing substantial amounts of unhealthy food advertising, banning advertising near playgrounds yielded a higher estimated reduction in exposure. It is also possible that such a ban might actually increase exposure to healthy food advertising, if some of the banned ads were replaced with healthy food advertisements. Support would likely be high for these bans, as seen through support for advertising bans for other harmful products including cigarettes, e-cigarettes and alcohol. Furthermore, such restrictions on unhealthy food marketing have repeatedly been identified as a cost-effective, and even cost-saving, population-based approach to reducing childhood obesity (Magnus *et al.*, 2009; Veerman *et al.*, 2009; Cecchini *et al.*, 2010; World Health Organization, 2012).

The use of wearable cameras, GPS devices and image, spatial and space-time analyses in this research enabled the identification of where and when children in this study were exposed to unhealthy food advertising in outdoor public spaces in their everyday lives. It also enabled the evaluation of the impact of potential interventions. To our knowledge, this is the first time such a method has been used in this way. The generated maps illustrate the findings in simple and innovative ways for policy-makers and the public. However, there are limitations to the research. The decision to code an image only if 50% or more of a brand name or logo could be seen likely underestimates the amount of advertising exposure. Furthermore, the use of still photography may

have missed some exposures. Children did not have equal numbers of images, thus, findings could be biased towards children with more images in the dataset. Second, noise and signal drop in the GPS led to missing data. Third, while this data was gathered in 2014/15 there have been no policy changes at national, regional or city level that have effected any change. Further analysis of the Kids’Cam dataset would enable analyses of policy interventions in other areas of advertising related to health, such as alcohol and gambling. Further research of exposure to advertising using such methods would be valuable, especially if it enabled the evaluation of policy interventions as occurred here.

From a policy perspective, this research has identified the extent of the problem of children’s exposure to unhealthy food advertising in outdoor public spaces. It highlights that children are exposed not only in children’s spaces but in a range of public settings and at key times during the day. This research identifies the impacts of a suite of potential interventions to reduce exposures and maps these in informative ways for policy-makers and the public. Such interventions to ban unhealthy food advertising in public places could make use of existing advertising restrictions on tobacco and alcohol.

CONCLUSION

This research provides real-time evidence that children are exposed to unhealthy food advertising in public outdoor spaces. Implementing bans on unhealthy food advertising in residential areas and within 400 m of schools and playgrounds in Wellington City would likely halve children’s exposure to unhealthy food advertising and contribute to the reduction of childhood obesity. Although this study was conducted in New Zealand, this research provides new methods and innovative findings likely relevant for policymakers in other jurisdictions as outdoor advertising is a prominent feature in many cities across the world.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Health Promotion International* online.

AUTHORS’ CONTRIBUTIONS

WL, AP and LS conceived of the study. LS, MS, MB, TC led Kids’Cam data collection. WL led spatial analyses, supervised by AP and TC. WL and AP led drafting of the Materials and Results. MB, LS and MS led drafting

of the Introduction and Discussion. All authors edited and approved the manuscript.

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ETHICAL APPROVAL

Approval of data usage was granted by the University of Otago Human Ethics Committee (13/220). School approval, child assent and parental consent were acquired in writing from participating schools, children and their parents.

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