International Journal of Public Health (2019) 64:625–635
https://doi.org/10.1007/s00038-019-01239-8

ORIGINAL ARTICLE

Obesity risk in women of childbearing age in New Zealand: a nationally representative cross-sectional study

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Received: 31 August 2018 / Revised: 10 March 2019 / Accepted: 25 March 2019 / Published online: 22 April 2019

Abstract

Objectives To investigate risk factors for women with obesity of childbearing age.

Methods A cross-sectional survey of New Zealand women (15–49 years) with measured height and weight was used [unweighted (*n* = 3625) and weighted analytical sample (*n* = 1,098,372)] alongside sociodemographic-, behavioural- and environmental-level predictors. Multilevel logistic regression weighted for non-response of height and weight data was used.

Results Meeting physical activity guidelines (AOR (adjusted odds ratio) 0.66, 95% CI 0.54–0.80), Asian (AOR 0.15, 95% CI 0.10–0.23) and European/other ethnicity (AOR 0.46, 95% CI 0.36–0.58) and an increased availability of public greenspace (Q4 AOR 0.55, 95% CI 0.41–0.75) were related to decreased obesity risk. Older age (45–49 years AOR 3.01, 95% CI 2.17–4.16), Pacific ethnicity (AOR 2.81, 95% CI 1.87–4.22), residing in deprived areas (AOR 1.65, 95% CI 1.16–2.35) or secondary urban areas (AOR 1.49, 95% CI 1.03–2.18) were related to increased obesity risk. When examined by rural/urban classification, private greenspace was only related to increased obesity risk in main urban areas.

Conclusions This study highlights factors including but not limited to public greenspace, which inform obesity interventions for women of childbearing age in New Zealand.

Keywords Obesity · Maternal · Women · Green space · New Zealand

Introduction

The global rise of women of a childbearing age (15–49 years) with obesity is a major public health concern internationally (Müller and Geisler 2017). It is associated with reduced female fertility, recurrent miscarriage and congenital malformations (Boots and Stephenson 2011; Gardosi et al. 2013; Godfrey et al. 2017). There are also consequences that extend across generations. For example, longitudinal evidence shows that being obese before pregnancy resulted in a twofold increase in the risk of offspring obesity (ages 6–11 and 12–19 years) (Leonard et al. 2017). Given the varying demographic and environmental conditions, and the large potential health return, exploring the risk factors for women with obesity of childbearing age is warranted.

To prevent adverse maternal and child health outcomes, a healthy body composition is important (Bautista-Castaño et al. 2013; Hanson et al. 2017). However, evidence of the effectiveness of preconception interventions for improving such outcomes for mothers is scarce (Barker et al. 2018). Two recent Lancet series have highlighted the importance of innovation in the design and delivery of affordable and scalable interventions to improve maternal health (Black et al. 2013; Ceschia and Horton 2016). Investigating both individual- and area-level risk factors for all women of

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00038-019-01239-8) contains supplementary material, which is available to authorized users.

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childbearing age, including those not immediately intending to become pregnant, is therefore worthy of exploration. The causes of obesity are multidimensional (Caprio et al. 2008; Ohri-Vachaspati et al. 2013) influenced by individual-level factors such as age and gender, and larger social-, cultural-, economic- and environmental-level contexts in which individuals live. Recent evidence has suggested that interventions might be constrained by focusing on individual responsibility, and not directly addressing the challenge of social influences or an obesity-promoting environment (Barker et al. 2018).

Although evidence has examined the contribution of sociodemographic and behavioural factors to obesity risk in women of childbearing age (Agha et al. 2014; El-Sayed et al. 2011; Johns et al. 2014), questions remain about environmental-level risk factors. With policy focus shifting towards environmental-level approaches internationally (Department of Health 2011; Gateshead Council 2015) and within NZ (Ministry of Health 2018), such an understanding is crucial for establishing policy priorities and distributing resources (Ohri-Vachaspati et al. 2013). Some researches within the UK (Burgoine et al. 2017) and Australia (Astell-Burt et al. 2013) relate a low availability of greenspaces and increased availability of fast-food outlets to increased obesity risk. However, other studies, including those within NZ, are often more uncertain (Cobb et al. 2015). For instance, a previous study found little evidence for an association between neighbourhood access to supermarkets/convenience stores and fruit and vegetable consumption (Pearce et al. 2008). This also supports more recent international reviews and longitudinal and experimental evidence which is inconsistent in terms of how environmental-level risk factors may contribute to obesity risk. While research has looked at greenspace quality at a local level (Hobbs et al. 2017a), less research has differentiated between types of environmental features such as public or private greenspaces at a national level which may be important in uncovering associations with obesity (Pearson et al. 2014).

The interaction between individual- and area-level factors such as greenspace is rarely captured. However, obesity is disproportionately represented in individuals within deprived areas which also have poorer quality environments, i.e. more fast-food outlets and air pollution (Black et al. 2014). Environmental- and individual-level factors may act together with compound obesity risk in this population. Previous UK-based research has shown that favourable physical activity (PA) environments were most beneficial for those individuals of higher socio-economic status (Hobbs et al. 2017b). While it is not possible to explore all interactions between different individual- and area-level factors, differential environmental effects by socio-economic status seem to be a worthy area of investigation. Our study uses a nationally representative cross-sectional survey with measured height and weight to examine sociodemographic- (e.g. age, ethnicity), behavioural- (e.g. PA) and area-level (e.g. greenspace, food outlets) risk factors for women with obesity of a childbearing age.

Methods

Participants and settings

The 2016/17 New Zealand Health Survey (NZHS) collects cross-sectional sociodemographic and health behaviour information. Height (cm) and weight (kg) were measured by a trained interviewer using a standardised procedure and calibrated equipment (Ministry of Health 2017). BMI was then calculated for each participant as weight (kg)/height (m^2). Obesity is defined as BMI > 29.99. While it is not a direct measure of body fat, previous research has suggested that BMI is useful for understanding obesity prevalence in epidemiological studies (Green 2015). The NZHS selects participants who usually reside in New Zealand (with the exception of those in most types of non-private dwelling and those inhabiting islands other than the North, South and Waiheke Islands), using a multistage, stratified, probability-proportional-to-size sampling design (Ministry of Health 2017). This approach is aimed at increasing the sampling of Māori, Pacific and Asian participants. Prioritised ethnicity was used within this study which involves each person being allocated to a single ethnic group based on the ethnic groups they have identified with, which are, in order of priority: Māori, Pacific, Asian and European/Other. This means that if someone identifies as being Chinese and Māori, they are classified as Māori for the purpose of analysis. Results are weighted to account for survey design, oversampling and non-response in height- and weight-related questions. This provides representative results for the New Zealand adult population. From an original sample of 13,599 adults, only women of childbearing age (15–49 years) were extracted resulting in an unweighted final sample of 3625 women. BMI for pregnant respondents was not included as their weight would not reflect their 'usual' weight.

Variables: individual- and area-level risk factors

An overview of risk factors is provided in Table 1. Briefly, sociodemographic-, behavioural- and environment-level factors were included in the regression model as predictors. The data available within the NZHS were supplemented with environmental-level variables. Meshblocks were already attached to the customised NZHS data when supplied. Meshblocks are defined as the smallest geographical

Table 1 Definitions and descriptions of variables included in the analysis grouped by layers (sociodemographic, behavioural and environmental) of the socioecological model (New Zealand 2016/17)

Variable	Data source	Other information
Age	MoH NZHS 2016/17	Included as continuous variable of years
Years		
Gender		Binary outcome (0 = male; 1 = female)
Male		
Female		
Ethnicity		Included as prioritised ethnicity (1 = Maori; 2 = Pacific; 3 = Asian; 4 = European/other)
Māori		
Pacific		
Asian		
European/other		
Education level		Four levels of education (1 = less than upper secondary; 2 = upper secondary; 3 = tertiary; 4 = other)
Less than upper secondary		
Upper secondary		
Tertiary		
Other		
Physical activity		Active means meeting the recommended levels of physical activity (0 = not meeting guidelines; 1 = meeting guidelines) (Ministry of Health 2015)
Not active		
Active		
Fruits and vegetables		Meeting both the fruit and vegetable guidelines (0 = not meeting guidelines; 1 = meeting guidelines) (Ministry of Health 2015)
Do not meet guidelines		
Meet guidelines		
Drinking		Hazardous drinking (AUDIT score > = 8) on NZHS. (0 = hazardous drinking; 1 = not hazardous drinking)
Hazardous		
Not hazardous		
Smoking		Identifies as a current smoker (0 = No; 1 = Yes). Current smoker is defined as smoked at least 100 cigarettes in lifetime and smoking daily, weekly or monthly
Non-smoker		
Smoker		
Area-level deprivation	University of Otago (2013)	Combines census data relating to income, home ownership, employment, qualifications, family structure, housing, access to transport and communications for each meshblock in New Zealand (5 indicates that a meshblock is in the most deprived 20% of areas in New Zealand)
Q1 (least deprived)		
Q2		
Q3		
Q4		
Q5 (most deprived)		
Urban/rural areas	Statistics New Zealand (2013)	
Main urban area		1 = Main urban area
Minor urban area		2 = Minor urban area
Rural/other		3 = Rural/other
Secondary urban area		4 = Secondary urban area
Food outlets	Open Street Map (2018)	
No access		0 = No access
Access		1 = Access

Table 1 (continued)

Variable	Data source	Other information
Private greenspace	The greenspace dataset used in the analyses was based on the GIS layer produced by Richardson et al. (2010)	1 = Quartile 1 (lowest % of greenspace) 2 = Quartile 2 3 = Quartile 3 4 = Quartile 4 (highest % of greenspace)
Q1 (< 11% of meshblock)		
Q2 (11–37%)		
Q3 (38–57%)		
Q4 (> 57%)		
Public greenspace		
Q1 (< 6% of meshblock)		
Q2 (6–9%)		
Q3 (10–14%)		
Q4 (> 15%)		

unit for which statistical data are collected and processed by Statistics New Zealand (the 2013 Census comprised 46,629 units). Approval to access the NZHS data was granted by the New Zealand Ministry of Health. Area-level summarised spatial data were assigned to survey responses based on the geographical area of the respondent; then, participant identifying information was removed. These processes were undertaken by the Ministry of Health. As such, all data used in analyses were anonymised prior to our use. All de-identified data were password protected and kept in a secure computer facility.

National coverage of food and alcohol outlet environmental-level data was sourced from OpenStreetMap (29 May 2018). Variables extracted and downloaded as point data were fast-food outlets, supermarkets and greengrocers, alcohol and convenience stores. Access to all types of food outlets was included as one category, as food outlets often cluster together based on the need for customer demand (Hobbs et al. 2017c). A full breakdown of classification details is shown in supplementary material S4. Greenspace was sourced from three nationwide datasets: the Land Cover Database (LCDB2), Land Information New Zealand's (LINZ) 2004 Core Records System and the Department of Conversation (DoC) 2003 Boundaries dataset (Richardson et al. 2010). Greenspace was divided into private (e.g. farmland) and public (e.g. public parks) greenspaces. The Statistics New Zealand definition of main urban areas, secondary urban areas, minor urban areas and rural was used to classify areas women lived in. Due to low statistical power in some covariates, for instance ethnicity, these areas were classified as main urban areas and 'other'. Other comprised secondary urban, minor urban and rural areas. To define the availability of food outlets, food outlet locations were linked to NZ meshblocks. The number of food outlets was counted using a point in polygon analysis within each meshblock. The greenspace measure was calculated as a percentage of the meshblock dedicated to either public or private greenspace, both in ArcGIS 10.4.1 (ESRI Inc, Redlands, CA). Risk behaviours were measured in line with the NZHS guidelines; however, further information including the question, answer and how those answers were categorised is provided in supplementary material S5.

Statistical analysis

Descriptive statistics were presented as mean (standard deviation) or as n (%) to summarise key predictor variables and outcomes. Multilevel logistic regression (adjusted odds ratio, 95% confidence intervals) was used to investigate the relationship between risk factors and obesity for all analyses. Multilevel models account for the clustering of observations within meshblocks. Sampling weights were used to approximate a nationally representative sample, and weights also accounted for non-response in those individuals who did not provide height and weight measurements. A weighted sample of 1098,372 individuals were used for multilevel regression analyses ($n = 3526$ unweighted sample). All analyses adjusted for age, gender, ethnicity, education level, meeting physical activity guidelines, meeting fruit and vegetable guidelines, drinking hazardously, smoking status, area-level deprivation, urban/rural classification, food outlets and private and public greenspaces and hence the reporting of adjusted odds ratios. To explore the effects of greenspaces by area-level deprivation, an interaction term was fitted, and results were also stratified by rural/urban classification. In this study, obesity is defined as a dichotomous variable (in which there are only two possible outcomes, i.e. obese or not obese). An adjusted odds ratio (AOR) for any independent variable gives the relative amount by which the odds ratios of the outcome increase (obesity) (AOR greater than 1) or decrease (AOR less than 1) when the value of the independent variable is increased by 1 unit adjusting for other covariates. All analyses were completed using STATA v14.5.

Results

Descriptive statistics

This study estimates that 31.8% of women of childbearing age (15–49 years) were obese (Table 2). Compared to those not obese, those women classified as obese were over-represented by those of: Māori or Pacific ethnicity, educated to less than upper secondary, not meeting the PA guidelines, not meeting the fruit and vegetable guidelines and residing within the most deprived areas. There were inconsistent differences by availability of greenspace and few differences by food outlet availability. Obesity prevalence increased with higher levels of deprivation, and prevalence was greater in women from rural and the most deprived areas and lowest in rural areas and the least deprived areas (supplementary material Figure S1).

Sociodemographic, behavioural and environmental determinants of obesity

The results from the multilevel logistic regression model weighted for non-response of height and weight measurements, exploring how sociodemographic, behavioural and environmental factors were related to obesity, are presented in Table 3. Sociodemographic risk factors included age and ethnicity. For women in this study, obesity risk increased with age. Compared to women aged 15–24, those aged 25–34 (adjusted odds ratio (AOR) 2.24, 95% confidence intervals (CI) 1.67–3.01), 35–44 (AOR 2.26, 95% CI 1.96–3.51) and 45–49 had a higher likelihood of being obese (AOR 3.01, 95% CI 2.18–4.16). Strong effects were also noted for ethnicity. Compared to Māori women of childbearing age, Pacific women were more likely to be obese (AOR 2.81, 95% CI 1.87–4.22), whereas Asian (AOR 0.15, 95% CI 0.10–0.23) and European women (AOR 0.46, 95% CI 0.36–0.58) were less likely to be obese. There was no association for education level.

Behavioural risk factors included low levels of PA. Women were at lower risk of obesity when meeting the PA guidelines (AOR 0.62, 95% CI 0.51–0.76), compared to those who do not meet them. There was no association for women meeting the recommended fruit and vegetable intake (AOR 0.83, 95% CI 0.54–1.02), compared to those who do not meet them. While there were small differences in the descriptive statistics, alcohol consumption and smoking (AOR 1.30, 95% CI 0.995–1.709) were unrelated to obesity risk.

At the environmental-level and area-level deprivation, urban/rural classification and private and public greenspaces within residential areas were associated with obesity risk. To compare relative effects, private and public greenspaces were split into quartiles (private: Q1 $<$ 11%; Q2 11–37%; Q3 38–57%; Q4 $>$ 57%; public: Q1 $<$ 6%; Q2 6–9%; Q3 10–14%; Q4 $>$ 14%). Increased availability of private greenspace was related to increased risk of obesity (Q2 AOR 2.11, 95% CI 1.61–2.75; Q3 AOR 2.24, 95% CI 1.70–2.99; Q4 AOR 1.98, 95% CI 1.14–2.65) compared to those with the lowest percentage of private greenspace within their residential meshblock (quartile 1). An increased availability of public greenspace was related to a lower risk of obesity (Q3 AOR 0.74, 95% CI 0.56–0.98; Q4 AOR 0.55, 95% CI 0.41–0.75) compared to those individuals with the lowest percentage of public greenspace within their residential meshblock (quartile 1). Compared to main urban areas, those women in secondary urban areas were more likely to be obese (AOR 1.50, 955 CI 1.03–2.18). There was no association for any type of food outlet.

Association between determinants of obesity, variation by rural/urban and area-level deprivation

It was hypothesised that the relationship between risk factors and obesity may differ for women in urban and rural areas (supplementary material Table S1). Due to low numbers, data on minor urban, secondary urban and rural areas were combined into one category of 'other'. Main urban areas were retained as one category. The relationship between nearly all risk factors and obesity was substantively the same across different main urban and 'other' areas. However, the relationship between private greenspace and obesity was only present in main urban areas. Compared to those with the least private greenspaces (Q1), those who resided in main urban areas (Table S1) with a higher availability of private greenspace were at increased risk of obesity (Q2 AOR 2.94, 95% CI 2.18–3.96; Q3 AOR 2.73, 95% CI 1.95–3.82; Q4 AOR 2.71, 95% CI 1.89–3.89). There was no relationship in 'other' areas. The beneficial effect of public greenspace was slightly stronger within rural areas. Residing within deprived areas was more strongly related to increased risk of obesity but only in 'rural and other' areas. Compared to those in the least deprived quintile (Q1) in rural areas, those in Q5 (most deprived quintile) (AOR 3.28, 95% CI 1.49–7.23) and Q4 (the second most deprived quintile) (AOR 2.79, 95% CI 1.32–5.87) were more likely to be obese. This supports our

Table 2 Description of demographic-, behavioural- and environmental-level characteristics categorised as obese or not obese *n* (%) (New Zealand 2016/17)

Risk factors	Not obese (n = 2221)	Obese (n = 1035)	Not obese (ratio)	Obese (ratio)
Sociodemographic				
Age				
15–24	531 (23.3)	217 (16.1)	0.71	0.29
25–34	741 (32.5)	411 (30.5)	0.64	0.36
35–44	686 (30.1)	461 (34.2)	0.60	0.40
45–49	319 (14.0)	259 (19.2)	0.55	0.45
Ethnicity				
Māori	434 (19.1)	480 (35.6)	0.47	0.53
Pacific	71 (3.1)	196 (14.5)	0.27	0.73
Asian	414 (18.2)	52 (3.9)	0.89	0.11
European/other	1358 (59.6)	620 (46.0)	0.69	0.31
Education level				
Less than upper secondary	408 (17.9)	344 (25.5)	0.54	0.46
Upper secondary	602 (26.4)	475 (35.2)	0.56	0.44
Tertiary	1109 (48.7)	445 (33.0)	0.71	0.29
Other	133 (5.8)	69 (5.2)	0.66	0.34
Missing	25 (1.1)	15 (1.)	0.63	0.37
Behavioural				
Physical activity				
Not active	1113 (48.9)	743 (55.1)	0.60	0.40
Active	1153 (50.6)	595 (44.1)	0.66	0.34
Missing	11 (0.5)	10 (0.7)	0.52	0.48
Fruits and vegetables				
Do not meet guidelines	1377 (60.5)	885 (65.7)	0.61	0.39
Meet guidelines	900 (39.5)	463 (34.3)	0.66	0.34
Drinking				
Hazardous	386 (17.0)	317 (23.5)	0.55	0.45
Not hazardous	1869 (82.0)	1016 (75.4)	0.65	0.35
Missing	22 (1.0)	15 (1.1)	0.59	0.41
Smoking				
Not smoker	1838 (80.7)	932 (69.1)	0.66	0.34
Smoker	433 (19.0)	413 (30.6)	0.51	0.49
Missing	6 (0.3)	3 (0.1)	0.66	0.34
Environmental level				
Area-level deprivation				
Q1 (least deprived)	353 (15.5)	98 (7.3)	0.78	0.22
Q2	400 (17.6)	158 (11.7)	0.72	0.28
Q3	509 (22.4)	222 (16.5)	0.69	0.31
Q4	485 (21.3)	338 (25.1)	0.59	0.41
Q5 (most deprived)	530 (23.3)	532 (39.5)	0.49	0.51
Urban/rural classification				
Main urban area	1720 (75.5)	972 (72.1)	0.64	0.36
Other[a]	557 (24.5)	376 (27.9)	0.60	0.40
Food outlets				
No access	2146 (94.2)	1271 (94.4)	0.66	0.34
Access	131 (5.8)	76 (5.6)	0.63	0.37
Private greenspace				
Q1 (< 11%)	621 (27.3)	247 (18.3)	0.72	0.28
Q2 (11–37%)	567 (24.9)	432 (32.0)	0.57	0.43

Table 2 (continued)

Risk factors	Not obese (n = 2221)	Obese (n = 1035)	Not obese (ratio)	Obese (ratio)
Q3 (38–57%)	557 (24.5)	319 (23.7)	0.64	0.36
Q4 (> 57%)	532 (23.3)	350 (26.0)	0.60	0.40
Public greenspace				
Q1 (< 6%)	609 (26.7)	367 (27.2)	0.62	0.38
Q2 (6–9%)	470 (20.6)	313 (23.2)	0.60	0.40
Q3 (10–14%)	708 (31.2)	406 (30.2)	0.64	0.36
Q4 (> 15%)	490 (21.5)	262 (19.4)	0.65	0.35

Analysis based on weight sample and adjusted for non-response in weight outcomes such as obesity

Unweighted n

[a]Other includes minor urban area, rural and secondary urban area

initial descriptive graph presented in supplementary material Figure S1.

An interaction term between public greenspaces and by area-level deprivation quintile was investigated in terms of obesity risk. Area-level deprivation is represented by quintiles while greenspace is separated into quartiles to compare relative effects. Those residing within the least deprived areas with the lowest access to public greenspaces were used as the reference group. There was little evidence to support a difference by socio-economic status by area-level deprivation quintile (supplementary material Table S2).

Discussion

Main findings of this study

Using a nationally representative cross-sectional survey with measured height and weight, this study investigated the relationship between individual- and area-level risk factors and women with obesity of childbearing age. Multilevel models revealed that both individual- (i.e. age, ethnicity and meeting physical activity guidelines) and area-level factors (i.e. public and private greenspaces, area-level deprivation and rural/urban classification) explained risk of obesity to some degree. This study extends existing evidence, showing that environmental-level interventions such as increasing access to public greenspace may vary by different types of areas, for instance urban or rural areas. More specifically, the adverse effect of an increased availability of private greenspace was only related to increased obesity risk in main urban areas, while increased public greenspace was more strongly associated with obesity in rural and other areas. Our findings are directly relevant for policymakers in public health and planning that are increasingly considering employing multilevel interventions to improve public health for women of childbearing age. This study confirms that interventions to tackle obesity should be multilevel. However, it specifically highlights the importance of considering how environmental-level interventions can be maximised for those individuals or areas most at risk, for instance, those residing in different rural/urban areas. Acknowledging the multilevel and interactive effects between individual- and area-level factors may be an important future research direction and focus for policy when focusing on women with obesity of childbearing age.

What this study adds

It is well documented that amongst countries in the OECD, New Zealand has one of the highest rates of adult obesity (Ministry of Health 2015). Our findings support previous longitudinal and nationally representative New Zealand evidence, which show significant inequalities for individuals residing within socio-economically deprived areas and Māori and Pacific ethnicities (Ministry of Health 2017). For instance, while strong effects were noted in this study, this reflects wider population trends which show that 50% of Māori and 69% of Pacific adults (total population) were obese in the NZHS 2016/17 compared to 30.5% of European/other adults (Richardson et al. 2010). However, in New Zealand, the mechanisms as to why these inequalities in obesity prevalence persist are poorly understood. For instance, obesity is multifaceted, and some have posited that apparent differences by ethnicity are due to variation in genetic factors (Rush et al. 2009). However, our study also highlights that those who met the PA guidelines were at lower risk of obesity compared to those who did not meet the guidelines, respectively. While fruit and vegetable consumption was non-significant, effects trended in the expected direction. Previous New Zealand-based research has shown that poor dietary behaviours and less physical activity are associated with higher prevalence of childhood obesity and that these relationships were most

Table 3 Relationships between individual- and environmental-level variables and obesity risk in women of childbearing age (New Zealand 2016/17)

Variable	Risk factors (AOR, 95% CI)
Age (years)	
15–24	REF
25–34	*2.243, 1.672–3.008**
35–44	*2.263, 1.959–3.518**
45–49	*3.011, 2.177–4.163**
Ethnicity	
Māori	REF
Pacific	*2.809, 1.871–4.221**
Asian	*0.151, 0.098–0.234**
European/other	*0.460, 0.362–0.584**
Education	
Less than upper secondary	REF
Upper secondary	1.112, 0.847–1.461
Tertiary	0.803, 0.609–1.057
Other	0.892, 0.569–1.398
Physical activity	
Not active	REF
Active	*0.661, 0.542–0.807**
Fruits and vegetables	
Do not meet guidelines	REF
Met guidelines	0.839, 0.542–1.027
Drinking	
Hazardous	REF
Not hazardous	1.059, 0.825–1.361
Smoking	
Not smoker	REF
Smoker	1.304, 0.995–1.709
Area-level deprivation	
Q1 (least deprived)	REF
Q2	1.262, 0.869–1.831
Q3	1.133, 0.798–1.608
Q4	*1.810, 1.274–2.572**
Q5 (most deprived)	*1.650, 1.158–2.349**
Urban/rural classification	
Main urban area	REF
Minor urban area	0.999, 0.700–1.426
Rural/other	1.104, 0.812–1.499
Secondary urban area	*1.498, 1.027–2.187**
Fast-food outlets	
No access	REF
Access	0.999, 0.538–1.853
Supermarkets and greengrocers	
No access	REF
Access	0.904, 0.294–2.783
Convenience stores	
No access	REF
Access	1.073, 0.601–1.914
Private greenspace	
Q1 (< 11%)	REF
Q2 (11–37%)	*2.109, 1.613–2.754**
Q3 (38–57%)	*2.249, 1.695–2.985**
Q4 (> 57%)	*1.984, 1.148–2.651**
Public greenspace	
Q1 (< 6%)	REF
Q2 (6–9%)	0.835, 0.618–1.128
Q3 (10–14%)	*0.742, 0.558–0.987**
Q4 (> 14%)	*0.558, 0.418–0.745**
Variance	0.066, 0.005–0.799

AOR adjusted odds ratio

significant for Pacific children (Utter et al. 2010). While less research has been done in mothers of childbearing age in New Zealand, our study corroborates current policy that physical activity and to a lesser extent dietary behaviours are related to lower risk of obesity in women of childbearing age in New Zealand (Ministry of Health 2015).

Previous research has shown inconsistent findings when relating the food and PA environment to obesity risk (Cobb et al. 2015). Our study confirmed such inconsistencies, as food outlet availability was unrelated to obesity risk. This may be due to the use of OpenStreetMap which has an unknown accuracy and completeness for food outlets within New Zealand at present. However, further work is needed to deliberate the accuracy of such sources within a New Zealand context. Despite this, effects were noted by percentage of public and private greenspaces and risk of obesity. In our study, increased percentage of public greenspace in residential neighbourhoods was related to a lower risk of obesity. In contrast to this study, much previous evidence is inconsistent. A recent systematic review relating greenspace to obesity concluded that evidence was equivocal and varied by measure and population (Lachowycz and Jones 2011). Within New Zealand, previous research has suggested that greenspace variation may have lesser relevance for health in part because greenspace is generally more abundant and there is less social and spatial variation in its availability than found in other contexts (Richardson et al. 2010). Despite this, more recent studies have shown that different types of greenspaces may be associated with health outcomes such as PA, obesity and quality of life (Panter et al. 2017; Ward and Aspinall 2011). This study therefore adds important evidence, highlighting how those with the highest availability of public greenspaces were at the lowest risk of obesity. However, it is also plausible that this beneficial effect of increased greenspace availability may not be distributed evenly across in society.

The concept that environmental-level interventions may impact on different populations has rarely been applied in this context or population. In our study, there was little evidence that associations between greenspace exposure and obesity differed when stratified by area-level deprivation. This is in contrast to previous UK-based research (Hobbs et al. 2017b) which showed that a favourable PA environment was beneficial for those of higher education only. This does, however, raise an important conceptual problem of considering who environmental-level interventions are for and how they can be maximised for those in at-risk areas or populations, for example people residing within different area types. While food and alcohol outlets were not related to obesity, other evidence suggests that effects of environmental-level interventions such as improving access to greenspaces or food outlets will be maximised when considering how the environmental interventions can work best for those of different population groups, for instance, those of lower socio-economic status (Burgoine et al. 2017). This is extremely important as environmental-level interventions may have the potential to increase health inequalities, if the intervention benefits those least deprived areas (Hobbs et al. 2017b). This concept of a differential effect by population group or area type is supported by results within this study which showed that private greenspace was related to increased obesity risk but only in main urban areas. However, it is also plausible that this association may be an artefact which is affected by residual confounding by another variable not fully adjusted for within this study in main urban areas and is worthy of further investigation.

Strengths and limitations of this study

There is a wide range of risk factors used which allow a comprehensive consideration of several individual- and area-level risk factors and assessment of their associations with obesity. Moreover, obesity was defined by a height and weight that was measured by a trained individual. The survey is also nationally representative which allows conclusions to be generalised to New Zealand. Despite some strengths, this study is cross-sectional which does not allow the monitoring of change in obesity status over time which would allow causal inference. While various risk factors were included, more area-level risk factors such as measures of perceptions of the environment would have helped more accurately depict the relationship between neighbourhood environments and obesity risk.

Future research would benefit from linking children and parent relationships to disentangle associations between the parent and child and obesity risk in both populations simultaneously. It is known that there is a greater prevalence of early life risk factors for a Pacific or Māori child, including having a mother with obesity (Howe et al. 2015); however, further research is required to better understand the links between child, parent and environmental risk factors and risk of childhood obesity. Food outlet data were sourced from OpenStreetMap due to the need for national coverage of food outlets. While OpenStreetMap is increasingly used for research purposes, the location of specific features such as food outlets has not been validated which may have contributed to some of the null associations seen with food outlets. In addition, neighbourhoods were defined as meshblocks; however, it would have been beneficial to have actual food purchases and PA behaviours geocoded as the current approach assumes that accessibility equals use. Extensively discussed within previous research, this also does not account for availability of greenspaces or food outlets in the work or commuting environments which may contribute to a significant amount of variation in obesity risk (Kwan 2018). While height and weight were measured, it is plausible that variations may exist by ethnicity not accounted for in this analysis.

Conclusion

The present study used a nationally representative cross-sectional survey with measured height and weight to explore risk factors for women with obesity of childbearing age in New Zealand. Several individual- and area-level factors were related to obesity risk, and our study compliments existing evidence which suggests multidimensional interventions are critical for effective intervention. For instance, an increased availability of public greenspace within the residential neighbourhood was related to lower obesity risk, yet an increased availability of private greenspace within residential neighbourhoods was only associated with increased obesity risk in main urban areas only. However, there was little evidence that public greenspace differed for obesity risk by area-level deprivation. Based on this evidence, successful obesity prevention strategies should focus on individual-level risk factors but also consider environmental-level factors such as public greenspace exposure. Consequently, the multilevel interaction between different individual- and area-level factors may be an important future direction for research in determining associations for different populations. Policy may also wish to consider how the benefits of environmental-level interventions can be maximised for those populations or areas most at risk.

Acknowledgements This research was carried out as part of the GeoHealth Laboratory work programme at the University of Canterbury, funded by the New Zealand Ministry of Health. The authors thank the participants of the 2016/17 New Zealand Health Survey. Access to the data used in this study was provided by the New Zealand Ministry of Health under conditions designed to keep individual information confidential and secure in accordance with requirements of the Health Information Privacy Code 1994 and the Privacy Act 1993.

Funding This research was carried out as part of the GeoHealth Laboratory work programme at the University of Canterbury, funded by the New Zealand Ministry of Health.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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