Investigating change in the food environment over 10 years in urban New Zealand: a longitudinal and nationwide geospatial study

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Abstract

Background:

While it is likely that changing food environments have contributed to the rise in obesity rates, very few studies have explored historical trends in the food environment with little if any at a nationwide level.

Method:

This longitudinal, nationwide, and geospatial study aims to examine change over time in food environments in all urban areas of New Zealand from 2005 to 2015 using high quality food outlet data by area-level deprivation and within the three largest urban areas of Auckland, Christchurch and Wellington. We hypothesise that distance and travel time by car to supermarkets and fast-food outlets will have decreased over time with the most notable decreases in distance occurring in the most deprived areas of urban New Zealand. Change in major chain “fast-food” and “supermarket” outlets as identified by Territorial Authorities between 2005 and 2015 was analysed through the use of multilevel regression models.

Results:

Findings show a decrease in travel distance and time to both fast-food outlets and supermarkets. However, the biggest decrease in distance for supermarkets was seen in the most deprived areas.

Conclusion:

Our findings contrast and add to previous evidence to demonstrate how changes in the food environment are not uniform and vary by area-level deprivation and by city with more equitable access to supermarkets occurring over time.

1. Introduction

Unhealthy diets and obesity are persistent global threats to public health that also present significant challenges for effective intervention (1). The burden of disease from unhealthy diets and high body weight are significant; in 2017, 11 million (95% uncertainty interval [UI] 10–12) deaths and 255 million (234–274) disability-adjusted life-years were attributable to diet (2, 3). Over the past decades, populations have shifted their diets from traditional diets high in cereal and fibre to diets that are high in sugar, fat and animal-based foods (4-6). This shift coincides with economic, demographic and epidemiological changes referred to as the 'nutrition transition' (6). However, even in this new era of the nutrition transition, dietary practices continue to change. For example, an ever-increasing proportion of the household food budget is spent on eating out of the home (7, 8). In addition to, or coinciding with, changing norms about the role of food in society, the increase in availability of food sources is facilitating away-from-home food purchases (9, 10) and greater consumption of fast-foods and sugar sweetened beverages (4, 5). Other evidence shows that the consumption of unhealthy energy dense, nutrient poor foods is often observed among those individuals who frequent fast-food outlets or cafes (7).

The recognition that exposure to social and environmental factors may be driving poor diets and health, warrants policy action. Epidemiological studies are important to help identify leverage points for interventions and policies (1, 11-14). A plethora of studies have attempted to estimate how neighbourhood food environments may be driving changes in dietary patterns, body mass index (BMI) and obesity. However, evidence is often inconsistent with findings often showing no or even counterintuitive links between the food environment and body weight (12, 13, 15-18). Consequently, to best use epidemiological evidence to identify leverage points we need to understand population drivers of poor health outcomes that are environmentally and socially determined and changes in the wider ecological context in which behaviours are constructed rather than focusing on the individualisation of risk (19-22).

The evidence for the role of the food environment and how food environments change over time is often limited by several shortcomings including methodological and conceptual limitations (13, 23). First, food environment studies often rely on commercial food environment databases that can be inaccurate in both the location and temporal information of the food establishments (20). Second, studies are often

missing key details within the methods on the food outlets extracted and construct definitions; leading to calls for greater clarity to ensure methods and findings are transparent and comparable (13). Third, studies do not always investigate if there is heterogeneity in change by different regions or cities which may be masked by analysing only overall or nationwide patterns. Finally, there is often a reliance on cross-sectional study designs (13, 14). This limits our ability to examine change over time and draw causal inferences in more robust longitudinal or natural experiment study designs (20). Indeed, while longitudinal studies do exist for changes in health outcomes and behaviours, fewer longitudinal studies examine changing trends in food environments, with even fewer longitudinal studies conducted outside of the American-centric evidence base (24). Taken together, these considerations further reinforce the need for this study.

This study first analyses historical information from 2005 and 2015 to investigate trends in the food environment over time, specifically the proximity to fast-food and supermarket food establishments across all urban areas of New Zealand. It then investigates if change in proximity to the food environment varies by area-level deprivation. Finally, it investigates if changes in proximity to the food environment differ by the urban areas of Auckland, Christchurch, Wellington, and– the three largest cities in New Zealand. We hypothesise that 1) distance and travel time by car to fast-food and supermarket outlets will decrease over time and 2) there will be increasing disparities by area-level deprivation, such that the distance and travel time by car decreases the most in those areas defined as highly deprived.

2. Methods

2.1 Study settings and geographic scale

This research focuses on all urban areas of New Zealand defined using the Statistics New Zealand Urban Areas Classification 2018, based on major urban areas with a population of 100,000 or more and large urban areas with a population of 30,000 to 99,999 (25). This is because data on environmental exposures in urban areas are more reliable (12), a substantial proportion of the New Zealand population live in urban areas, and urban areas reflect similar geographic properties to one another (12). For this study, we used 2018 urban area data as our base, then selected the data for urban areas from 2006 that fell within these boundaries using ArcGIS 10.7.1. In New Zealand, urban areas remained fairly similar between 2006 and 2013, however these are greatly reduced in size for 2018 due to newly introduced classification replacing older geographical standards (25), despite there being more urban areas in total (25). This is because urban areas were recently redesigned to represent the urban 'footprint' (i.e., areas of high population density), whereas previously urban areas represented the urban footprint plus the surrounding commuting zone. An overview of urban areas included in the study are shown in Figure 1, equating to 22,095 population weighted centroids in 2006 and 29,369 in 2018.

INSERT FIGURE 1 HERE

2.2 Food environment

We evaluated two distinct categories of food outlets at two time points (2005 and 2015) which were, 1) “fast-food” and 2) “supermarkets”. Fast-food outlets were defined as multinational food outlets, including McDonald’s, Burger King, Kentucky Fried Chicken, Pizza Hut, Subway, Domino’s Pizzas, and Dunkin’ Donuts. “Fast-food” outlets often have negative connotations due to the nutrient poor, energy dense foods sold. “Supermarkets” are generally the largest and most prevalent suppliers of healthy food (13). Examples of major chain supermarkets included in our dataset were New World, Pak'nSave, Countdown, Fresh Choice, and Four Square.

2005 food outlet data

Data in 2005 were obtained from all Territorial Authorities (TAs) across New Zealand during the same year. In New Zealand, TAs have a regulatory responsibility to maintain a list of all premises in their respective region used in the manufacturing, preparation and/or storage of food for sale. Data were verified using an online telephone directory and, in the case of missing data, were supplemented with additional address information. These data were coded into two groups: 1) a total of 458 major chain fast-food outlets were identified and 2) data on outlets selling healthier food were also collected from TAs including all supermarkets, resulting in 221 major chain supermarkets. All outlets were geocoded to provide precise geographic coordinates of each location.

2015 food outlet data

Data in 2015 were also sourced from all TAs across New Zealand (12). Any missing records for data were supplemented with additional searches from the Ministry for Primary Industries (MPI) website (12). MPI are responsible for registering all food franchises that manufacture, prepare or sell food products. Closed premises were removed and if duplicate entries for one premise were given only the latest registration was kept, however, duplicate business names at different locations were kept as unique records (12). Data were geocoded using Google Maps Geocoding Application Programming Interface (API), at the address level of precision, and the geographic coordinates for any unmatched records were located manually. A total of 622 fast-food outlets and 304 supermarkets fell within the urban areas and were included in the study.

Defining access

With this geocoded information on food establishment data, we created multiple food environment measures based on driving distance. For each food establishment type, we estimated the driving distance and travel time by car via the road network from residential areas to the closest food outlet (further details on the road network can be found within the technical paper by Beere et al. (26)). Residential areas from 2005 were defined using meshblock population weighted centroids from the Census 2006, and in 2015 were defined using meshblock population weighted centroids from the Census 2018. As outlined in Figure 1, only urban areas of New Zealand were considered.

2.3 Area-level deprivation and changes in geography over time

We used the New Zealand Index of Deprivation (NZdep) 2006 index data to provide a temporal match to 2005 food outlet data and NZdep2018 index to provide a temporal match to 2015 food outlet data. These were joined to the population weighted centroids of meshblocks in 2006 and 2018 respectively.

NZDep2006 combines nine variables from the 2006 census which reflect eight dimensions of deprivation. NZDep2006 provides a deprivation score for each meshblock in New Zealand. Meshblocks are geographical units defined by Statistics New Zealand, containing a median of approximately 87 people in 2006. NZDep2006 (27) combines the following nine census data variables: 1) Income - people aged 18-64 receiving a means tested benefit; 2) Income - people living in equivalised (methods used to control for household composition (28)) households with income below an income threshold; 3) Owned home - people not living in own home; 4) Support - people aged <65 living in a single parent family; 5) Employment - people aged 18-64 unemployed; 6) Qualifications - people aged 18-64 without any qualifications; 7) Living space - people living in equivalised households with occupancy threshold; 8) Communication - people with no access to a telephone; 9) Transport - people with no access to a car. Data were split into deciles with areas defined as least deprived (Decile 1) up to the most deprived areas in New Zealand (Decile 10).

Data on area-level deprivation in 2018 was obtained from NZDep2018 which combines nine variables from the 2018 census that reflect eight dimensions of material and social deprivation (29). Data were again split into deciles with areas defined as least deprived (Decile 1) up to the most deprived areas in New Zealand (Decile 10). We use both NZDep 2006 and 2018 as small changes between deprivation indices over time have emerged. For instance, in creating NZDep2018 there were several notable changes. First, the way of defining small areas has been adjusted to benefit from Statistics New Zealand's newest small geographical areas. Second, two variables in the index have had minor adjustments, one removing a previous age restriction (Internet access), and the other resulting from changed income categories in the census form (low income). In addition, a new deprivation variable (damp/mould) has replaced a previously relatively low-performing one (no access to a car). By using both NZDep 2006 and NZDep 2018 we account for such change.

2.4 Statistical analysis

First, to examine the median distance to food outlets over time we used the road network distance from meshblock centroid to the nearest food outlet (26). The travel distance (in metres) and travel time (minutes) by car to the nearest food outlet along the road network was calculated using the GIS network analysis functionality, specifically the closest facility analysis in ArcGIS Pro 2.4. Relative percentage change was then calculated to allow a standardised difference for all outlets (((Distance 2015 - Distance 2005) / Distance 2005) *100). One-way ANOVA were used to test the difference between decile of deprivation and median distance to food outlets. We then created multilevel models with time as the independent variable and geographical areas (district health board) as the clustering variable to account for the clustering of observations within geographical areas. We controlled for population density, as this may be an important factor for access to food outlets. To test whether the average change in the count of food retailers was different according to area-level deprivation, we tested effect modification by adding an interaction term 'year' by 'area-level deprivation (both NZDep2006 and NZDep 2018)' to each model. Statistically significant interactions were then plotted using post estimation and marginal means of outcome for levels of each covariate. Due to the non-normal distribution of proximity data two transformations were explored to address non-uniform distribution of residuals. First data were log transformed and second, a square root transformation was applied. Residuals were normally distributed for log-normal models and provided substantively the same outcomes as raw data, as shown in the supplementary materials. For ease of interpretation, statistical analyses were performed on the raw proximity data using Stata SE version 16.0 (StataCorp, College Station, TX, USA), and two-tailed $\alpha=0.05$ defined significance.

3. Results

3.1 Change in the food environment

Between 2005 and 2015, the number of fast-food outlets and supermarkets in urban New Zealand increased from 458 to 622, and from 221 to 304 respectively. Table 1 shows the descriptive statistics for change in the food environment over time and by area-level deprivation. In line with our first hypothesis, the median travel distance to fast-food outlets and supermarkets decreased over time. For instance, median distance to fast-food outlets decreased from 1,744m to 1,557m while median distance to supermarkets decreased from 1,827m to 1,401m. Similar decreases were noted by travel time.

3.2 Change in the food environment over time and by area-level deprivation decile

Both distance to fast-food outlets ($p<0.001$) and supermarkets ($p<0.001$) varied by neighbourhood deprivation decile in 2005 and 2015 (Table 1). In 2005 for instance, the median distance to fast-food outlets decreased with higher levels of area-level deprivation (Dep 1: (low deprivation) 2,670m; Dep 9: 1,355m). However, there was a slight increase in distance in the most deprived decile (Dep 10: 1,719m) ($p<0.001$). For supermarkets in 2005, compared to the least deprived decile (Dep 1: 2,090.62m) the median distance was shorter in the more deprived areas (Dep 9: 1,625m) again with a noticeable increase in the most deprived decile (Dep 10: 2,156m). For example, the distance to fast-food outlets in 2015 decreased as area-level deprivation increased (Dep 1: 2,379m; Dep 9: 1,239m) again with an increase in the most deprived decile (Dep 10: 1,624m). For supermarkets in 2015, the median distance to supermarkets again decreased as area-level deprivation increased (Dep 1: 1,757m; Dep 9: 1,255m) with a slight increase in the most deprived area (Dep 10: 1,400m). In summary, when considered by area-level deprivation, descriptive statistics show that travel distance and travel time appear to have decreased the most from 2005 to 2015 for fast-food outlets in the least and moderately deprived areas whereas for supermarkets a notable decrease in median travel distance was noted for the most deprived decile (Dep 10) for supermarkets from 2005 to 2015, decreasing from 2,156m to 1,400m.

The relative change in median distance (m) is shown within Table 2 from 2005 to 2015. As expected the relative change was very similar between distance (m) and time (minutes). Overall, the relative change was higher for supermarkets than fast-food outlets. The largest relative change was for supermarkets in the most deprived areas (Dep 10) which had a decrease of 35% for median distance

while the smallest relative changes occurred in the least deprived areas. In contrast, for fast-food outlets the smallest relative change occurred in the four most deprived deciles (Dep 7 – Dep 10) with the largest relative changes occurring in the moderately deprived areas (Dep 4 – Dep 6).

INSERT TABLE 1 AND 2 HERE

3.3 Change in the food environment in Auckland, Christchurch and Wellington

A visual representation of change over time nationally as well as by the three major cities of Auckland, Christchurch and Wellington are shown below. Figure 2 shows fast-food outlets and Figure 3 shows supermarkets. Figure 2 also shows a comparison of median distance to fast-food outlets by deprivation for New Zealand and selected major urban areas of Auckland, Christchurch and Wellington. Christchurch and Wellington, areas with similar population sizes but different urban structure, show shorter distances to fast-food outlets in 2015 throughout most deprivation categories. The decrease in median distance to fast food outlets from 2005 to 2015 is strongest in the case of Wellington, which also shows greater differences in median distance between deciles of area-level deprivation than for the whole country and for the cities of Auckland and Christchurch. Also, a social gradient (except in the most deprived areas) that reflects the overall pattern of nationwide data is visible in both urban areas where the distances to fast-food outlets are longer in less deprived areas. In contrast, in Auckland the biggest urban area in New Zealand, the distances to fast-food outlets are generally longer, and the social gradient is less apparent from Dep 4 onwards. Moreover, in contrast to the general trend, the median distance to fast-foods increased in 2015 when compared to 2005 in areas with deprivation Dep 4 or higher.

A general social gradient, again with the exemption in Dep 10, is also present in median distances to the closest supermarket, although the difference is weaker than for median distance to fast-food outlets. The population in all categories of deprivation has closer proximity to a supermarket in 2015 than it had in 2005. When we compare the three major urban areas, the most noticeable decrease in the median distance to the closest supermarket in 2015 was in Auckland where the most substantial change happened in more deprived areas, resulting in more equitable access to supermarkets across all area-level deprivation categories. While changes in supermarket accessibility were minor in Wellington,

Christchurch generally showed an increase in the median distance to the closest supermarket in 2015 when compared to 2005.

INSERT FIGURE 2 AND 3 HERE

As shown in Table 3, effects remained significant after adjusting for population density and area-level deprivation in Table 3 (see supplementary materials for log transformed models). Proximity (distance) to both fast-food (b= -211.13 [95% CI -239.01, -183.25]) and supermarkets (b= -927.07 [95% CI -960.29, -893.85]) reduced over time such that distance to the nearest outlet was reduced even after adjusting for population density and area-level deprivation. As shown within Table 4 a significant interaction was noted for supermarkets and area-level deprivation ($p<0.001$) such that the largest decreases in distance over time was seen in those most deprived deciles particularly Dep 7 (b= -424.75 [95% CI -575.95, -273.53]), Dep 8 (b= -544.78 [95% CI -694.09, -395.48]), Dep 9 (b= -431.82 [95% CI -577.71, -285.92]) and Dep 10 (b= -509.77 [95% CI -656.99, -362.53]). In contrast there was no evidence of a statistically significant interaction for fast-food outlets after controlling for population density (similar trends were seen for driving time see supplementary materials Table S3 and S4).

INSERT TABLE 3 AND 4 HERE

4. Discussion

This national longitudinal study investigated how access to fast-food outlets and supermarkets have changed in the urban food environment in New Zealand between 2005 and 2015. We confirm our first hypothesis that the median distance by car to both supermarkets and fast-food outlets decreased over time. Distance to fast-food outlets decreased from 1,744m in 2005 to 1,557m in 2015 (b= -211.13 [95% CI -239.01, -183.25]) while distance to supermarkets decreased from 1,827m in 2005 to 1,401m in 2015 (b= -574.54 [95% CI -684.08, -464.27]). Changes were also noted by area-level deprivation over time. In contrast to our initial hypothesis, study findings by area-level deprivation show that travel distance and travel time by car decreased the most for supermarkets in the most deprived deciles. While a notable decrease was seen for travel distance and time for supermarkets in the more deprived parts of urban New Zealand this pattern was not replicated for fast-food outlets. Interestingly, these results suggest that changes in the food environment of urban New Zealand have not been unfavourable as access to supermarkets has improved in the most deprived areas over the last decade. However, it is important to note that this has only occurred in urban areas of New Zealand and other areas may not have experienced such positive equitable changes. Moreover, it is still concerning that proximity to fast food in urban areas was short (around a three minute drive) already at baseline and has now become even shorter over time.

Very few studies have evaluated historical trends in the food environment (21, 22, 30, 31) with even fewer at a national level. Our study shows that travel distance and time to both supermarkets and fast-food outlets decreased over time. This is somewhat similar to longitudinal evidence from the Netherlands which showed that neighbourhoods in 2018, as compared to 2004, had a 120% increase in the count of food delivery outlets, 35% increase in the counts of restaurants, 24% decrease in count of local shops however, there was no significant difference for supermarkets (22). A recent UK longitudinal study found a general increase of 45% in the availability of takeaway outlets over an 18 year period which supports our results showing a decrease in distance and travel time in New Zealand (21). Results in our study go beyond much previous evidence to show differences by city. For instance, the most noticeable decreases in median distance to the supermarket in 2015 were observed in Auckland compared to Wellington and Christchurch. This may be due to the fact that in Auckland distances tended to be much larger than in the other two areas or it is likely that such differences in how the food

environment changes over time may be due to the different national and local contexts and associated policy, environmental, and economic influences bespoke to each country and city in which the studies are being carried out (8, 12, 13, 20-22, 30). For example, Christchurch generally showed an increase in the median distance to the closest supermarket in 2015 when compared to 2005. However, this pattern which was bespoke to Christchurch and may reflect some of the effects of the substantial social and economic upheaval of the earthquake sequence which hit the city in 2011 that caused catastrophic damage to the infrastructure of the city (32).

When examined by area-level deprivation the decreases in travel time and distance in this study were confirmed for supermarkets in the most deprived deciles. However, there was little difference for fast-food outlets. Interestingly, findings do not support international evidence that shows food environments commonly considered as healthy tend to be located in less deprived areas (33-35). Results instead demonstrate that highly deprived neighbourhoods have high accessibility of both unhealthy and healthy food environments. Such relationships differ from those found in research from North America, but are similar to relationships found in previous New Zealand research considering various types of outlets (12, 36-38). This may be due, in part, to historical and cultural factors that have shaped not only population composition but also the spatial provision and perceptions of food retailers. For example, these results differ from previous longitudinal evidence over 40 years from the US which demonstrated that access to fast-food increased more rapidly for those living in low poverty census tracts, such that disparities in proximity to fast-food diminished over time (20). Uniquely, that study also assessed workplace exposure and showed that workplaces in poorer census tracts also had lower proximity to supermarkets and higher proximity to fast-food at baseline. However, this disparity disappeared over time (20). This is similar to UK based evidence which showed that deprived areas had the greatest density of takeaway food outlets, and they also had the greatest increase in takeaway food outlet density across the study period of 18 years (21). Yet, recent evidence which showed considerable changes in the Dutch foodscape over a 14 year period indicated a change towards a higher availability of food retailers offering convenience and ready-to-eat foods (22). Our findings which show better access to supermarkets in the most deprived areas contrasts with research from the Netherlands which showed little evidence for increasing disparities in access to supermarkets during the study period (22). However, this difference could be due to the role of supermarkets in different countries, cultures and

type of food sold which may vary significantly between New Zealand and other countries and contexts (13, 39, 40).

Indeed, rural New Zealand could manifest very different findings to those presented within this study which focuses only on urban New Zealand. Moreover, our lack of change by area-level deprivation could be due to our definition of fast-food only containing major chain fast-food outlets and not more locally operated smaller takeaway outlets. Previous research from New Zealand has included a range of such locally operated outlets, finding significant associations between deprivation and geographic accessibility (35-38). Such research often uses differing definitions of food outlets categories however and employs various methodological approaches, making direct comparisons difficult. For example, while all of these studies included data on multinational and local fast food outlets, supermarkets, and convenience stores, Pearce et al. (2007) classified healthy food outlets as all supermarkets, convenience stores and service stations selling fresh food. This contrasts other New Zealand research (12, 36) which categorises convenience stores and service stations as unhealthy due to the disproportionate amount of pre-packaged foods when compared to fresh foods. Furthermore, various methodological approaches have been used including median travel distance, density, Euclidean buffers, network buffers, gravity-based models, and food environment indices (13). While this makes direct comparisons difficult, it is worth noting that, despite the methodological approach used, these studies all found a social gradient whereby access to a range of retail options increased in highly deprived areas. Explanations behind this patterning are likely reflective of many facets. Notably, the price of land values and zoning measures in New Zealand play an important role in the location of food outlets. For example, lower rental costs and restrictions of business locations may encourage businesses to cluster in highly deprived areas. Additionally, public resistance to certain businesses in affluent areas many compound such spatial patterns.

The policy implications from this study are profound. First, this study shows that access to supermarkets have improved in urban areas particularly within deprived areas; providing powerful longitudinal evidence which better informs the conversation about the proliferation of food outlets in urban areas in New Zealand and internationally. While this may reflect other factors such as an increased demand for such services in particular urban areas, this results in more equitable access to supermarkets across

all area-level deprivation categories. Second, while associations between the food environment, diet and obesity remain heavily contested and inconsistent, fast-food outlets are often said to provide energy dense and nutrient poor foods, inundating more healthy food options (41-43). Of concern in this study, is that proximity to fast food in urban areas was incredibly short around (3 minute drive time) already at baseline and has become even shorter over time (less than three minutes). This means that there are a lot of opportunities for improving the urban food environments in New Zealand, such that healthier choices are made easier and unhealthier choices are made more difficult. While evidence for the direct effects of unhealthy foods environment on population health is inconsistent, it is likely the absence of evidence is due to methodological limitations (23) rather than a true absence of such influence. Indeed, the sheer density of food establishments in our current urban environments are likely to influence food choice independent of individual level factors via easy and convenient access, thereby making them more likely to be chosen as a food source (44) where a flood of sensory cues can encourage people to eat even when they may not require food (45).

This study has several strengths and weaknesses which should be considered when interpreting study findings. First, it is important to note that our study addresses several weaknesses of previous studies by examining change over time, across different cities and by comparing both supermarkets and fast-food outlets. We examined ten years of longitudinal food environment data. We used multiple measures of access to the food environment by focusing on both fast-food and supermarket outlets. While we use all urban areas of New Zealand this misses important rural areas which may experience the food environment in a vastly different way. In addition, there are many other methods of measuring spatial accessibility that could be utilised including density measures, indices and gravity models. By only focusing on one measure in this study, there is the potential risk of not completely capturing changes in access. Despite this, some previous research has shown measures of density and proximity to be highly correlated (46). Furthermore, whilst we have both fast-food and supermarkets over time, a recent Dutch study showed a 120% increase in the count of food delivery outlets (22). This is an important part of the food environment that needs to be captured in future studies. We are also limited in this study by only focusing on major fast food chains, while there are many other types of smaller locally operated fast-food or takeaway outlets which were not captured by our measure of fast-food. In addition to this, while we have chosen NZDep indexes (2006 and 2018) that best align with food outlet data (2005 and

2015) there is still some temporal misalignment. Finally, there may be some element of contamination due to the Canterbury earthquake sequence which spurred mass population movement and future research could explore the effect of such population movement.

5. Conclusion

In summary, we observed changes in the New Zealand urban food environment over a 10 year study period. This analysis of trends in food environment exposure using high quality food outlet data demonstrated that the median distance to both supermarkets and fast-food outlets decreased over time for all areas of urban New Zealand. However, notable differences in change over time occurred with bespoke patterns by major urban area and by area-level deprivation for supermarkets. Findings in this study help researchers and policymakers better understand patterns of access to food over time especially when considered alongside increases in the prevalence of people with obesity over the past decades and the increasing trend of energy dense nutrient poor foods consumed outside of the home environment. Future longitudinal research with longer study follow-up periods and high quality measures of change in the food environment, body weight outcomes and if possible, dietary measures will help better understand the ways in which different populations interact with their local food environment and how this relates to change in body weight and obesity prevalence over a considerable length of time.

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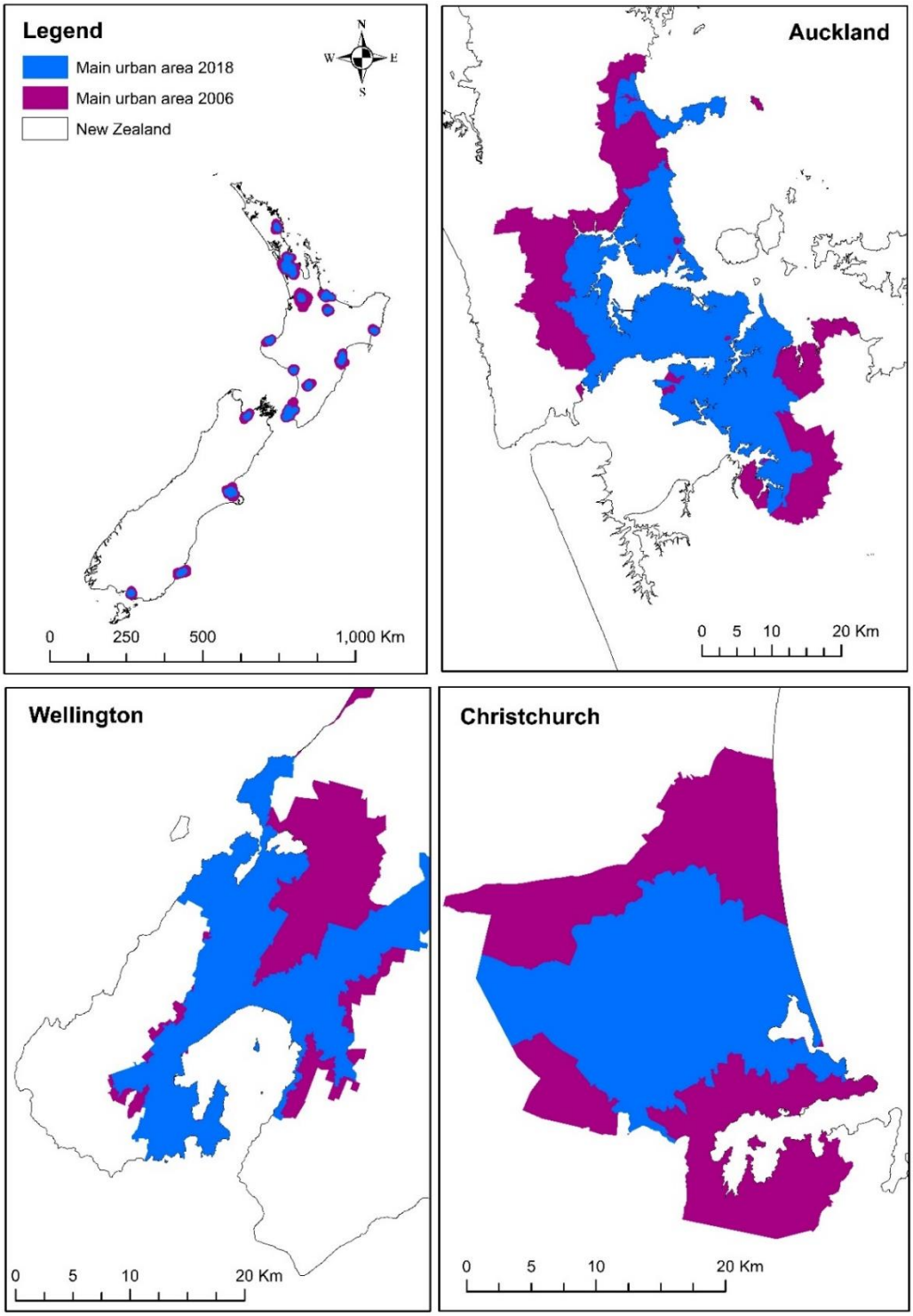

Figure 1. Change in urban areas from 2006 (purple) to 2018 (blue) for the whole of New Zealand with a focus on the three major urban areas of Auckland, Christchurch and Wellington.

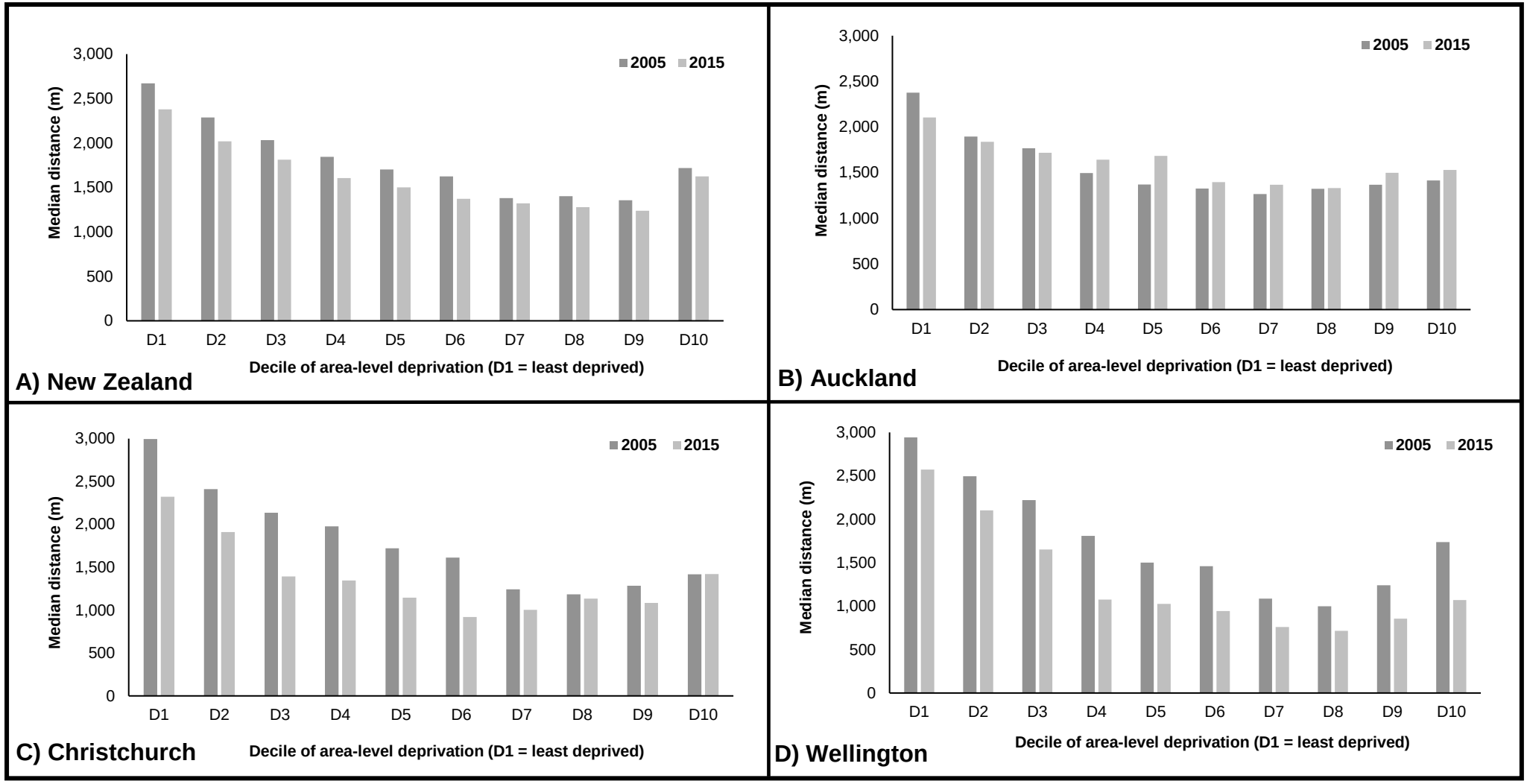

Figure 2. Median distance to fast-food outlets in 2005 and 2015 by area-level deprivation decile (D10 highest level of deprivation) (Panel A – Nationally; Panel B – Auckland; Panel C – Christchurch; Panel D – Wellington).

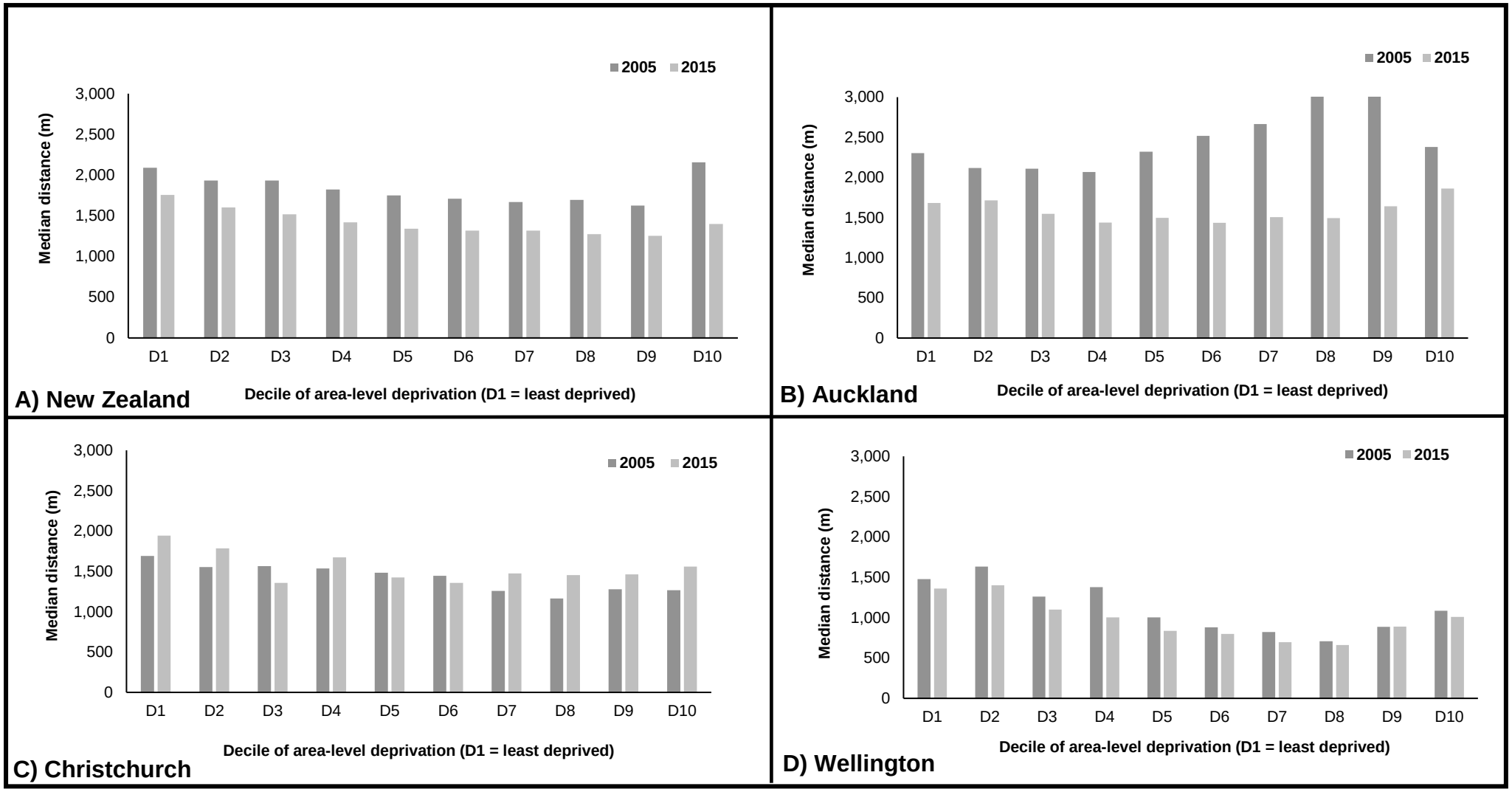

Figure 3. Median distance to supermarkets in 2005 and 2015 by area-level deprivation decile (10 highest level of deprivation) (Panel A – Nationally; Panel B – Auckland; Panel C – Christchurch; Panel D – Wellington).

Table 1. Median travel distance (meters) and time (minutes) by car to closest fast-food outlet, takeaway, and supermarkets in 2005 and 2015 by New Zealand area-level deprivation decile.

	2005				2015			
	Fast-food		Supermarket		Fast-food		Supermarket	
Decile[1]	Distance (m)	Time (min)	Distance (m)	Time (min)	Distance (m)	Time (min)	Distance (m)	Time (min)
Overall	1,744.11	3.31	1,827.49	3.52	1,557.76	2.97	1,401.78	2.70
Dep 1 (low)	2,670.74	4.97	2,090.62	3.96	2,379.07	4.50	1,757.43	3.35
Dep 2	2,286.53	4.28	1,931.98	3.71	2,019.68	3.89	1,601.21	3.08
Dep 3	2,033.17	3.82	1,934.18	3.71	1,812.72	3.48	1,518.68	2.92
Dep 4	1,844.86	3.46	1,824.33	3.46	1,606.17	3.09	1,419.69	2.74
Dep 5	1,703.08	3.12	1,751.47	3.38	1,500.81	2.89	1,340.79	2.58
Dep 6	1,625.21	3.07	1,708.91	3.26	1,371.03	2.64	1,318.62	2.56
Dep 7	1,380.70	2.61	1,668.20	3.22	1,321.37	2.51	1,319.70	2.54
Dep 8	1,400.69	2.69	1,694.41	3.30	1,278.65	2.43	1,275.94	2.43
Dep 9	1,355.40	2.61	1,625.79	3.13	1,239.17	2.35	1,255.12	2.41
Dep 10 (high)	1,719.27	3.29	2,156.83	4.12	1,624.75	3.06	1,400.62	2.71
Significance	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

[1]2015 data split by NZDep 2018 decile whereas 2005 food outlet data split by NZDep 2006 decile.

Table 2. Relative change (%) in median distance and time to closest fast-food outlet and supermarkets from 2005 and 2015 by New Zealand area-level deprivation decile.

	2005–2015 Change (%)			
	Fast-food		Supermarket	
Decile[1]	*Distance*	*Time*	*Distance*	*Time*
Overall	-10.68	-10.27	-23.29	-23.30
Dep 1 (low)	-10.92	-9.46	-15.94	-15.40
Dep 2	-11.67	-9.11	-17.12	-16.98
Dep 3	-10.84	-8.90	-21.48	-21.29
Dep 4	-12.94	-10.69	-22.18	-20.81
Dep 5	-11.88	-7.37	-23.45	-23.67
Dep 6	-15.64	-14.01	-22.84	-21.47
Dep 7	-4.30	-3.83	-20.89	-21.12
Dep 8	-8.71	-9.67	-24.70	-26.36
Dep 9	-8.58	-9.96	-22.80	-23.00
Dep 10 (high)	-5.50	-6.99	-35.06	-34.22
Significance	p<0.001	p<0.001	p<0.001	p<0.001

Table 3. Multilevel model results and associated 95% confidence intervals [CIs] from the final multivariable model of change in the food environment

	Fast-food distance b [95% CI]	Supermarket distance b [95% CI]
Time		
2005	REF	REF
2015	-211.13 [-239.01, -183.25] *	-927.07 [-960.29, -893.85] *
NZDep		
Decile 1 (least deprived)	REF	REF
Decile 2	-291.91 [-358.09, -225.72] *	-186.44 [-265.30, -107.59] *
Decile 3	-570.83 [-636.56, -505.10] *	-244.89 [-323.20, -166.57] *
Decile 4	-797.16 [-862.34, -731.99] *	-374.89 [-452.54, -297.24] *
Decile 5	-903.43 [-968.20, -838.65] *	-278.63 [-355.81, -201.44] *
Decile 6	-1124.62 [-1,188.90, -1,060.35] *	-361.08 [-437.67, -284.50] *
Decile 7	-1,303.25 [-1,367.09, -12239.40] *	-276.32 [-352.40, -200.25] *
Decile 8	-1,331.69 [-1,394.88, -1,268.51] *	-237.04 [-312.32, -161.74] *
Decile 9	-1,378.54 [-1,440.81, -1,316.27] *	-315.61 [-389.81, -241.42] *
Decile 10 (most deprived)	-954.68 [-1,017.98. -891.38] *	-165.12[-240.54, -89.70] *
Population density	-0.03 [-0.04, -0.03] *	-0.03 [-0.04, -0.03] *

Observations are nested within district health boards (43,949 observations with 17 groups [min 516; mean, 2,585; max, 6,161]. * = p<0.05.

Table 4. Multilevel model results and associated 95% confidence intervals [CIs] from the final multivariable model of change in the food environment

	Fast-food distance b [95% CI]	Supermarket distance b [95% CI]
Time		
2005	REF	REF
2015	-211.13 [-239.01, -183.25] *	-574.54 [-684.08, -464.27] *
NZDep		
Decile 1 (least deprived)	REF	REF
Decile 2	-281.84 [-372.18, -191.50] *	-130.70 [-238.28, -23.13] *
Decile 3	-509.16 [-598.62, -419.69] *	-78.65 [-185.19, 27.89]
Decile 4	-783.63 [-873.29, -693.97] *	-288.08 [-394.84, -181.31] *
Decile 5	-927.41 [-1,016.91, -837.91] *	-120.31 [-226.89, -13.73] *
Decile 6	-1,112.48 [-1,199.47, -1025.50] *	-202.65 [-306.25, -99.06] *
Decile 7	-1,323.48 [-1,410,68, -1,236.28] *	-87.82 [-191.67, 16.03]
Decile 8	-1,345.09 [-1,430.92, -1,259.26] *	10.72 [-91.48, 112.94]
Decile 9	-1,463.54 [-1,548.42, -1,378.67] *	-123.47 [-224.54, -22.39] *
Decile 10 (most deprived)	-1,007.81 [-1,094.14, -921.48] *	69.12 [-33.67, 171.93]
Time * NZDep Decile		
2015 * Decile 2	-17.13 [-149.77, 115.52]	-154.18 [-312.11, 3.76]
2015 * Decile 3	-123.46 [-255.09, 8.16]	-379.97 [-536.69, -223.25] *
2015 * Decile 4	-22.20 [-152.66, 108.19]	-222.72 [-378.01, -67.42] *
2015 * Decile 5	51.21 [-78.36, 180.78]	-363.49 [-517.76, 209.21] *
2015 * Decile 6	-21.63 [-149.81, 106.54]	-365.37 [-517.99, -212.75] *
2015 * Decile 7	44.73 [-82.26, 171.73]	-424.75 [-575.95, -273.53] *
2015 * Decile 8	31.28 [-94.12, 156.67]	-544.78 [-694.09, -395.48] *
2015 * Decile 9	169.07 [46.53, 291.60] *	-431.82 [-577.71, -285.92] *
2015 * Decile 10 (most deprived)	106.21 [-17.44, 229.86]	-509.77 [-656.99, -362.53] *
Population density	-0.03 [-0.04, -0.03] *	-0.03 [-0.04, -0.03] *

Observations are nested within district health boards (43,949 observations with 17 groups [min 516; mean, 2,585; max, 6,161]. * = p<0.05.