

Variation in health and social equity in the spaces where we live: A review of previous literature from the GeoHealth Laboratory

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Abstract

The previous decade has given rise to the importance of Geographic Information Systems (GIS) in explaining inequalities in health outcomes between groups based on their spatial location and social background. The GeoHealth Laboratory, based at the University of Canterbury, is a joint venture with the Health and Disability Intelligence unit within the Ministry of Health (MoH). The aims of this relationship are to add analytical capacity to MoH data collections and increase academic outputs of geospatial health research in New Zealand. GeoHealth research has often been a joint venture between Laboratory staff and students as well as collaboration with local and international researchers. These partnerships along with widely varied research interests have resulted in a large contribution of spatial health research in the field of health geography.

This article reports on research undertaken by the GeoHealth Laboratory that has focused on access to neighbourhood determinants of health. An overview of key neighbourhoods and health research areas are outlined within the over-arching themes of indices of access to neighbourhood factors, access to undesirable neighbourhood destinations, health promoting neighbourhood factors, access to and utilisation of health services, and complementary data collection and research groups within New Zealand.

Introduction

In 2004, the GeoHealth Laboratory was established as a means to increase geospatial health research capacity in New Zealand (Pearce, 2007). A joint venture between the Ministry of Health's (MOH) Public Health Intelligence group (PHI) and the University of Canterbury's Department of Geography, the aim of Geohealth Laboratory is to increase academic output of geospatial health research in New Zealand and to add analytical capacity to the data collected and held by the MOH. With an emphasis on how neighbourhood and national contexts shape health outcomes and inequalities, the Geohealth Laboratory

undertakes applied research in the fields of health geography, spatial epidemiology, and Geographical Information Systems (GIS). The strategic partnership with the PHI has offered rich opportunities help inform health policy research and decision making processes, particularly through the use of GIS to examine the environmental and social determinants of health and healthcare.

Up until relatively recently, GIS analysis of the inequalities in health outcomes at a neighbourhood scale were often generalised by social strata, such as socio-economic and/or ethnic groups. However, an increased awareness of the utility of GIS in the health sector, improved access to data, and the growth of more sophisticated health GIS methodologies, has made it possible for researchers to examine the contextual effects of neighbourhood composition on the health outcomes of individuals, and of wider populations more generally. The ability to focus on the places where people live and the characteristics of the local environment has become important in understanding inequalities in a range of health related behaviour, and health outcomes, within confined geographic environments such as urban areas. In New Zealand, research incorporating individual and population data has provided clear evidence of geographic inequalities in health between groups at varying spatial scales, from regional right down to neighbourhood levels.

At the scale of the neighbourhood, (Pearce, 2007) theorises that there are three contextual categories from which neighbourhoods might influence health: neighbourhood physical characteristics, social characteristics, and community resource access. These categorisations can, through plausible pathways, drive inequalities between individuals, social and ethnic groups, and between spatial/geographic groups (Pearce, 2007). GIS technology allows health geographers to integrate any number of spatial data, and increasing awareness of the effects of the built environment on health outcomes (Pearce, 2007) has required researchers to incorporate both physical and social datasets when analyzing the effects of neighbourhoods on health. Aspects of the built environment such as parks ('green space'), hospitals (health service provision), and shopping centres (amenities) are combined with underlying social demographics of specific areas and also the health outcomes of individuals living in these communities. In doing so, GIS has provided the opportunity to examine causal pathways between the physical and social attributes of neighbourhoods, and health behaviours and outcomes. Through this type of

integrated approach, GIS is able to produce more-representative estimates of community resource and health service access inequalities and barriers at varying spatial scales. Such research is key to producing effective health provision policy and has been a major focus of research output from the GeoHealth Laboratory since its inception.

This review article looks at the current body of research from the Geohealth Laboratory that has drawn on the contextual categories outlined by (Pearce, 2007) and examined neighbourhood access to factors in the built environment that can affect health outcomes. The first section focuses on methodology-based work that has sought ways to quantify inequality and to produce indices of accessibility. Second, work that has explored the relationship between how health-affecting factors in the built environment may drive socioeconomic and ethnic inequality is examined. Neighbourhood access to tobacco outlets, alcohol outlets, gambling opportunities, and food retailers are drawn on to tease out some of the complexities relating to neighbourhoods and health. Third, previously mentioned themes of neighbourhood inequality are explored further in the context of the physical environment, such as access to 'green space' and exposure to air pollution. Fourth, research into the relationship between travel time and secondary health service provision is reviewed to highlight inequalities that exist in health service accessibility and utilisation in New Zealand. Finally, we conclude by locating the literature reviewed in this article within the current objectives of the MOH.

Creating indices of access to factors in the built environment

The development of suitable metrics to assess geographical access to a range of health-related community resources is a key part of geospatial health research. As such, GeoHealth researchers, in conjunction with collaborators from external research groups, have been proactive in producing refining and benchmark indices to measure health inequalities. Pearce *et al.* (2006) created an index of key resources that are important in the local New Zealand context, and that have a plausible biological pathway to influencing health. Five domains were identified with specific sub-domains in most: 'recreational amenities' including parks, sports and leisure facilities, and beaches; 'shopping facilities' including supermarkets, dairies, fruit and vegetable stores, and service stations; 'educational facilities' including kindergartens, daycare/playcentres, primary schools, and intermediate/full primary schools; 'health facilities' including

general practitioners, pharmacies, accident and emergency, Plunket,¹ ambulance, and fire stations; and Marae.² For all of the 38,350 Census 2006 Meshblocks³ in New Zealand, accessibility to community resources was calculated using the travel time in minutes through the road network from the population weighted centroid within each meshblock to each sub-domain feature.

Nationally, beaches were the least accessible community resource, while parks were the most accessible. Both provide opportunities for exercise, and have been linked to positive physical and mental health outcomes. Access to shopping facilities was found to be better in urban compared to rural areas, while outdoor sport and leisure facilities were, as might be expected, more accessible in rural areas. Pearce *et al.* (2006) also demonstrated that variations exist between neighbourhoods in urban areas. For instance, there is greater access to shopping facilities sub-domains, such as fresh food retailers, near city centres. This pattern of access exists along major transport thoroughfares also. However, compared to central-city dwellers, those on the semi-rural periphery have much poorer access. Intra-urban variations in access to facilities such as daycare centres also followed this trend.

Building on this work, Pearce *et al.* (2007) drew on the New Zealand Deprivation Index (NZDep2006) - an area-level index of social deprivation - in combination with their prior community resource access indices to identify whether access inequalities exist across socioeconomic strata. With the exception of beaches, travel times to each sub-domain were shorter in the most deprived neighbourhoods compared to the least deprived. The ratio of travel time between the most deprived and least deprived neighbourhoods for each domain were as follows: 'recreational amenities' 0.70 ($p < 0.001$), that is total travel time in the most deprived areas was 30% shorter compared to the least deprived; 'shopping facilities' 0.47 ($p < 0.001$); 'educational facilities' 0.55 ($p < 0.001$); 'health facilities' 0.54 ($p < 0.001$); and Marae 0.48 ($p < 0.001$). This work was an important step in examining neighbourhood accessibility to resources in New Zealand, however the authors cited a number of limitations

¹ Plunket is an incorporated society formed in 1907, and is New Zealand's largest provider of care for children under the age of five.

² For Māori, the indigenous/first-nation people of New Zealand, Marae are ancestral village-type spaces integral to their mana (identity/pride/strength/respect).

³ Meshblocks are the smallest Census enumeration unit in New Zealand, each capturing a population of approximately 100 people.

that require attention in order to improve the assessment. In New Zealand, there is poor provision of public transport in many urban areas, and access to buses, taxis, and trains is largely non-existent in many rural areas. Further, because transport using private vehicles is itself patterned by socioeconomic status, the use of travel time as a determinant of access is not a uniform measure across groups. The index also did not take into account the quality, service capacity, and the population that was served by each resource. The fact that areas of high deprivation typically have higher population density,⁴ and therefore may require more community resources than less deprived areas, was also a limitation of the index.

Witten *et al.* (2011) subsequently developed a Neighbourhood Destination Accessibility Index (NDAI) for meshblock units in four New Zealand cities: North Shore City; Waitakere City; Wellington; and Christchurch. These four cities were selected due to their relatively high socioeconomic and built environment diversity. Witten *et al.* (2011) increased the number of domains developed by Pearce *et al.* (2007) to include: Education; Transport; Recreation; Social and Cultural; Food Retail; Financial; Health; and Other Retail. Each sub-domain destination was an everyday activity or community resource that, through close proximity, may encourage local residents from a range of ages and life stages to walk for leisure and/or transport.

The NDAI has applications for three main areas of social policy and planning: first, identifying resources in the built environment that increase activity levels, have the potential to improve health outcomes of community residents, and that may reduce health inequalities between geographic areas and social groups; second, transport planning can use this information to inform strategies targeted at increasing active transport (for example walking and cycling) and reducing the reliance on vehicles for relatively short trips; and third, the NDAI is a starting point for evaluating differences between neighbourhoods in access to community resources and the transport behaviour of local residents. Between neighbourhood variations in resource accessibility in the NDAI were consistent with previous work (Pearce *et al.*, 2006; Pearce *et al.*, 2007) as Witten *et al.* (2011) found that there is increased access to most

⁴ At the 2006 Census, population density was 3.3 times higher in the most deprived compared to the least deprived quintile.

resources in the index in more deprived areas compared to less deprived, after controlling for population density.

The previous indices focused on elements of the built environment, without being able to account for variations in underlying social factors that may influence the location of services, or how individuals will access and utilise them. Pearson *et al.* (2011), in their development of the Resilience Index New Zealand (RINZ), further emphasised the need to better understand the social cohesion of communities. In particular, attention was paid to the interactions between individuals and their neighbourhoods, instead of simply identifying the presence, or lack of, specific neighbourhood resources. RINZ was created with the aim of identifying characteristics in the built environment that may explain why some neighbourhoods have unexpectedly good health outcomes in the context of a relatively deprived socioeconomic setting. These are considered to be resilient neighbourhoods and the authors found they could be generally be typified as being in main urban areas, and having lower overall environmental deprivation, better access to safe drinking water, and lower access to gambling and alcohol outlets. Higher population density and a potentially protective factor attributed to Māori population density, both aspects of neighbourhood social composition, were also evident in the findings. The authors highlighted the importance of interactions between individuals and their neighbourhood, the perceptions residents have towards their local environment, and the role of social networks as important for understanding the role that social constructs play in promoting neighbourhood resilience.

Elements of social cohesion were explored further by Pearson *et al.* (2013) in their analysis of how socioeconomic isolation is associated with mental health outcomes among the most deprived neighbourhoods in Auckland. The authors created a spatial isolation index which quantified isolated areas that were deprived, yet surrounded by, affluent areas. These areas were believed to have high levels of 'social comparison' present where individuals are exposed to people of lower relative deprivation, which may in turn may affect negative views of the circumstances of their own lives. This is in contrast to residents of deprived neighbourhoods that are surrounded by areas with similar level of deprivation, which arguably may result in higher levels of social cohesion.

Among deprived neighbourhoods in Auckland, the most isolated deprived areas had 36% higher rates of anxiety/mood disorder compared to the least isolated deprived areas. The most isolated deprived areas also had 8% higher

rates of individuals with anxiety/mood disorder who were also receiving secondary treatment for alcohol/drug abuse. After adjusting for percent male, percent Māori, percent Pacific Peoples, and access to general practitioners (GPs), 56% higher levels of anxiety/mood disorder treatment were found in the most compared to the least isolated deprived neighbourhoods. This work has provided evidence to support the application of previous neighbourhood indices: communities with higher levels of social cohesion and interactions may improve the health outcomes and behaviours of those living there.

While not a complete solution in itself, the creation of indices in geospatial health research has enhanced our understanding of the patterns and processes that generate differences between neighbourhoods in New Zealand. The ability to identify and model spatial health inequality more effectively offers, among other things, more options for informing policy designed to increase the social capital within communities. Further, enhanced indices-based modelling techniques may assist in more cost-effective means to identify at-risk communities. Better understanding of where to target funding will help initiatives aimed at empowering communities to shape the future of their neighbourhood based on the collective attitudes, beliefs, and behaviours of the residents. In doing so, it is hoped cohesion and resilience can be improved at the community/neighbourhood level.

Inequalities in access to undesirable neighbourhood destinations

A major focus of neighbourhoods and health research conducted through the GeoHealth Laboratory has directed attention towards the role that factors in the built environment may play in contributing to inequalities between social and ethnic groups in New Zealand. In particular, access to neighbourhood provision of tobacco, alcohol, food sources, and gambling opportunities have been explored using a range of GIS techniques.

Tobacco outlets

Barnett *et al.* (2004) and Pearce *et al.* (2011) describe three major elements of the built and social environment within neighbourhoods that may influence individual smoking behaviour. First, material influences in healthy or unhealthy infrastructure and provision or lack of tobacco availability, may serve to increase or reduce smoking behaviour by influencing community norms. Second, social capital and neighbourhood social practices can serve to reinforce particular behaviours among residents. By example, neighbourhoods with low

social capital and social practices that see smoking as an acceptable behaviour are less likely to prevent initiation or encourage cessation among individuals. Third, place based regulation and policy targeting the retail tobacco environment by restricting availability and presence of tobacco products in outlets, and banning advertising of tobacco products in neighbourhoods and stores, is also strongly attributed to individual smoking behaviour at the neighbourhood level.

Pearce *et al.* (2008), in their analysis of retail tobacco outlets and individual smoking behaviour in New Zealand, found higher access to, and concentration of, tobacco outlets in more deprived areas. However, increased neighbourhood access to tobacco products in supermarkets and convenience stores was only moderately associated with higher levels of individual smoking. The authors state that effects may be different across groups, and that young people and sole parents who are more likely to lack adequate transport, may benefit most from restrictions on retail tobacco sales. Conversely, greater neighbourhood access and exposure to tobacco outlets may serve to normalise smoking behaviour, and in turn facilitate addiction and decrease the ability of individuals to quit.

Bowie (2011) examined adolescent smoking behaviour in relation to neighbourhood access to tobacco outlets, as well as the density of outlets around high schools. There was evidence of increased outlets in deprived neighbourhoods, but no evidence of variation in the number of outlets around deprived compared to affluent schools. Higher rates of adolescent smoking were associated with more outlets within 800m of neighbourhoods, however adjustment for area-level deprivation attenuated this relationship. Within 3000m of neighbourhoods, and after adjustment for deprivation, a positive association between outlet counts and female smoking rates remained. There was a negative association between outlet counts within 3000m and adolescent males and females who had never smoked. Because access to retail tobacco outlets is often high in both deprived and affluent neighbourhoods throughout New Zealand, it has been difficult to conclusively link access to smoking behaviour.

Alcohol outlets

Pearce *et al.* (2008) examined access to off-license alcohol outlets in New Zealand and found a clear social gradient when neighbourhoods were stratified by deprivation. The most deprived neighbourhoods had 4.99 more outlets per 100,000 residents compared to the least deprived. Variation in access was

demonstrated for all outlet types: hotels, taverns, or clubs (with an outlet per capita ratio between least and most deprived of 7.07); bottle stores (3.51); and supermarket/grocery stores (2.76). Within an 800m buffer from neighbourhood meshblock centroids, similar results were found. The most deprived neighbourhoods were 2.98 times more likely to have six or more outlets close by compared to the least deprived. This inequality in access to alcohol outlets is expected to drive inequalities in both drinking behaviour, and related health outcomes, between areas of high and low deprivation.

Pearson *et al.* (2013) used multiple GIS techniques to determine if socioeconomic inequalities in neighbourhood access to alcohol outlets were associated with alcohol/drug abuse treatment among individuals previously diagnosed with anxiety/mood disorder. Alcohol consumption is often used by individuals with anxiety/mood disorder as a self-coping strategy (Thomas *et al.*, 2005). This may lead to alcohol abuse among already vulnerable individuals, a behaviour that may be driven by greater access to alcohol outlets. Pearson *et al.* (2013) found that road network distance to the nearest outlet was associated with dual anxiety/mood disorder and with alcohol/substance abuse diagnosis. Areas in the quintile of best access had 37% higher rates of dual diagnosis than those with the worst access. Density of outlets within a 3000m road network buffer was also associated with dual diagnosis. Rates of dual diagnosis were 76% higher in areas with the best compared to the worst access. This research suggests that health and urban policy should enable Liquor Licensing Authorities to take into account access to existing outlets when granting new licenses.

Day *et al.* (2012) provides further support for measures that reduce the density of alcohol outlets, particularly in low socioeconomic neighbourhoods, as these areas are often home to vulnerable populations. Their work examined the relationship between outlet density and serious violent crime in New Zealand. After adjusting for neighbourhood deprivation, access to alcohol outlets was associated with higher levels of serious violence. In relation to Police station catchments, the quintile of areas that have the highest violent offences rates had 2-2.5 times more alcohol outlets compared to areas with the lowest rates. Low socioeconomic areas are already over-represented in violent crime statistics, and Day *et al.* (2012) demonstrate that the clustering of alcohol outlets in these areas may be an important driver of this.

Gambling opportunities

In New Zealand, there is a strong social gradient in problem gambling, with a much higher prevalence among low socioeconomic groups, as well as among Māori and Pacific populations. Rates of gambling have been shown to be approximately three times higher in the most deprived neighbourhoods compared to the least deprived, and gaming machines are also more prevalent in these areas. Pearce *et al.* (2008) examined neighbourhood access to gambling opportunities and individual gambling and problem gambling behaviour in New Zealand. They found that travel distance to the nearest gambling destination was typically double in the least deprived compared to the most deprived neighbourhoods. The median number of outlets within 5000m of neighbourhoods was also higher in the most (n=26) compared to the least (n=17) deprived neighbourhoods.

Pearce *et al.* (2008) identified that individual gambling behaviour was associated with neighbourhood access to gambling opportunities. After adjusting for individual and neighbourhood socioeconomic status and urban/rural status, closer proximity to any gambling venue type was positively associated with individual gambling, with an odds ratio of 1.51 between neighbourhoods with the greatest compared to the worst access. The same was true for density of outlets within a 5000m buffer, where an odds ratio of 1.67 was found for neighbourhoods with the greatest number of venues compared to neighbourhoods with no venues. Neighbourhood access to gambling venues was also positively associated with problem gambling among individuals. Neighbourhoods with the shortest distance to any type of gambling venue had a 2.05 times higher odds of problem gambling than those with the furthest distance. Such evidence supports recent local government moves to restrict the number of Class 4 (non-casino) gambling venue gaming machines, which are often in close proximity to residential areas.

Food retailers

Unlike alcohol, tobacco, and gambling opportunities, which all are identified as having negative impacts on neighbourhood health outcomes, access to food retailers has the potential to either promote or inhibit health outcomes, depending on the type of outlet. By example, fast-food outlets and convenience stores are locations where the availability of healthy food options is often limited. Clustering of unhealthy food outlets has led to the term ‘obesogenic environments’, an umbrella term coined to help frame research into how locational access to these retailers may affect weight related health

outcomes of local residents. In contrast with fast-food outlets, within the obesogenic literature, supermarkets, grocery stores, and produce vendors are most often regarded as providing consumers with the opportunity to make healthy food choices (Lovasi et al., 2009; Giskes et al., 2011).

In New Zealand, obesity rates have doubled in the past 25 years, and the nation now has the world's third highest rate of obesity. There is evidence of large social inequalities of obesity, with much higher rates among deprived groups, and these inequalities are evident between ethnic groups also (Pearce et al., 2007). Obesogenic environments have been suggested as a contextual factor in explaining the unequal social distribution of this growing epidemic. Obesogenic environments surrounding and within schools have received particular attention due to the high rates of obesity emerging among children and adolescents.

Pearce *et al.* (2007) found that exposure to unhealthy food options in school areas where children spend much of their time may influence the diet of students. Shorter travel distance to fast-food outlets was also evident around the most deprived schools across New Zealand. Spatial cluster analysis of this relationship from Day and Pearce (2011) found that there were three times more convenience stores and fast-food outlets within 800m of the most deprived schools compared to the least deprived. There was also evidence of school clustering of outlets nationwide, with higher than would be expected numbers of both fast-food and convenience stores within 1.5km of schools. Of concern is the higher ratio of outlets within a road network distance of 400m and 800m from schools, compared to the 1,200m and 1,500m buffers that were measured, as this indicates better access to unhealthy food outlets within relatively close walking distance from schools.

Pearce *et al.* (2007) also examined neighbourhood access to fast-food and healthy food retailing in New Zealand in relation to socioeconomic status. Nationally, significantly shorter travel distance to both international and locally operated fast-food outlets was found in the most deprived compared to the least deprived neighbourhoods. Distances to the nearest fast-food outlet were at least twice as far in the most compared to the least deprived areas. After adjusting for population density, the results were statistically significant. Access to supermarkets and other food retailers selling potentially healthier options was also better in the most deprived neighbourhoods. These findings were repeated in a follow up study from Pearce *et al.* (2008), which examined the density of

supermarkets, convenience stores, and fast-food outlets within 800m of New Zealand neighbourhoods.

Following this proximity analysis, Pearce *et al.* (2008) researched the effect of neighbourhood access to supermarkets and convenience stores on the fruit and vegetable consumption of local residents. Using travel time as the access measure, consumption of fruit was not associated with access to supermarkets or convenience stores in New Zealand. No association between consumption of vegetables and supermarkets was evident, however individuals in neighbourhoods with the best access to convenience stores had 25% lower odds of eating the recommended daily vegetable intake compared to those with the worst access. This may be representative of convenience stores being a source of generally unhealthy food choices, such as ready to eat foods and high sugar content drinks.

Using BMI data from the New Zealand Health Survey (2002/03), Pearce *et al.* (2009) subsequently examined the relationship between neighbourhood access to fast-food outlets and the diet related health outcomes of individuals. Compared to the findings relating to convenience store access in the previous study (Pearce *et al.*, 2008), recommended daily vegetable, but not fruit intake, was lower among residents of neighbourhoods with better access to fast-food outlets. In contrast to the expected outcome, the odds of being overweight were higher in neighbourhoods with the worst access to fast-food outlets. Based on this research, the authors concluded that neighbourhood access to fast-food outlets is unlikely to be a contextual driver of social inequalities in obesity in New Zealand.

In each of these studies, the authors note that while access may be better in deprived areas, the increased distance from affluent neighbourhoods is not large. Retailers selling both healthy and unhealthy food options may be attracted to low socioeconomic areas for reasons already outlined in this article, such as low land/rent costs, and a lack of community resistance. Despite a higher concentration of fast-food outlets being located in poorer neighbourhoods, these services are still highly accessible to individuals living in more affluent neighbourhoods.

The influence of neighbourhood physical environments on health inequalities

There are elements of the physical environment of neighbourhoods that may promote or inhibit health outcomes of the local community. Previous GeoHealth

Laboratory work has focused on access to green spaces, such as parks and reserves, which are believed to be associated with better physical and mental health outcomes. Inequalities and themes of social injustice relating to air pollution exposure, which is associated with ill-health, have also been explored.

Access to 'green space'

Access to recreational amenities in the neighbourhood environment has increasingly been studied in health geography literature. Neighbourhood environmental factors can be grouped into four categories: functional factors, such as street and path design and traffic flows; safety factors; neighbourhood aesthetics; and destinations (Pikora et al., 2003). Previous work has found that physical activity among residents increases with the number of recreational amenities nearby. The relationship varied by amenity type, use of sporting and recreational venues was less sensitive to distance than open spaces (Giles-Corti and Donovan, 2002; Giles-Corti et al., 2005). Higher rates of physical activity and lower obesity were observed in neighbourhoods with better access to leisure facilities, open green space, and beaches.

Witten *et al.* (2008), in their study of neighbourhood access to open spaces and the physical activity of residents, found little variation in BMI and physical activity and park accessibility. There was evidence of lower BMI among residents with the best access to the beach, after adjusting for socioeconomic status and urban/rural status. Respondents with the best access to the beach were also more likely to carry out recommended levels of physical activity and were less likely to be sedentary.

The role of green space and the effect on mental health has received considerable attention by health geographers. There are three proposed mechanisms for how green space can influence health: first, by providing increased opportunities for physical activity, improving both physical and mental health outcomes (Barton and Petty, 2012); second, increasing the opportunities for social interaction to occur (Zhou and Rana, 2012); and third, exposure to green space can provide restorative effects and reduce stress which has an etiologic association with chronic physical and mental illness (Ward Thompson et al., 2012). Internationally, low socioeconomic neighbourhoods have been shown to have poorer access to urban green space, and this may contribute to inequalities in physical activity and health outcomes between more and less deprived communities (Comber et al., 2008). As stated, more deprived neighbourhoods in New Zealand have been shown to have better access to green

space than less deprived areas (Pearce et al., 2007; Pearce et al., 2008). Subsequently, local literature has focused on the usable qualities of green space in relation to neighbourhood access and health outcomes.

Richardson *et al.* (2013) calculated the percentage coverage of total and usable green space within New Zealand Census Area Units⁵. Usable green space was defined as urban parkland; open spaces; beaches; and non-commercial, accessible forestry. The authors examined the association between the proportion of neighbourhood green space and two causes of mortality: Cardiovascular disease (CVD), which might be associated with green space through effects on physical activity and stress; and lung cancer, which was not expected to be associated with green space due to a very small link to physical activity. There was a contrasting socioeconomic gradient in neighbourhood green space coverage, where increasing deprivation was associated with lower total, but higher usable, green space coverage. This research found no association between CVD and either total or usable green space after adjusting for area level demographics, deprivation, smoking rates, and air pollution. The authors considered that a lack of variation in exposure to green space between New Zealand neighbourhoods, together with the high amount of green space in private gardens that were not included in the model, were limiting factors in their research into neighbourhood green space on health. Richardson *et al.* (2013) argue that focusing on the quality of green space and the neighbourhood environment may be a better predictor of health than green space quantity alone.

Further to this work, Richardson *et al.* (2013) examined the association between total neighbourhood green space and four health outcomes: CVD, overweight/obese, poor general health, and poor mental health. The role of physical activity as a mediator in these associations was also investigated. After adjusting for individual-level covariates, neighbourhood green space coverage was associated with lower risk of both CVD and poor mental health. Individuals living in the quintile of neighbourhoods with the highest proportion of green space had higher levels of physical activity, including physical activity. Although Richardson *et al.* (2013) argue that their findings only partially explained the relationship between green space and health, this work was the first to find positive associations between green space and health in New Zealand.

⁵ Statistical boundaries that usually have a population between 3000 to 5000 individuals and that vary in geographic size.

Nutsford *et al.* (2013) derived a range of neighbourhood to green space access measures to examine the relationship with anxiety/mood disorder treatment in Auckland, New Zealand. For both total and usable green space, the authors calculated road network distance to the nearest green space, proportion of green space within 300 meters, and proportion green space within 3000 meters from each meshblock. Distance to the nearest usable green space was associated with anxiety/mood disorder treatment counts. Nutsford *et al.* (2013) found that every 100m decrease in distance to usable green space resulted in 3% lower treatment counts. The proportion of green space within 3000m was also associated with mental health. For each 1% increase in both total and usable green space, anxiety/mood disorder treatment dropped by 4%. This research supports two hypotheses of how green space can influence health outcomes: first, through exposure to a restorative and stress-reducing environment and; second, the authors suggest a physical activity component based on the relationship between distance to nearest usable green space.

Richardson *et al.* (2013) and Nutsford *et al.* (2013) have identified the potential for future work to further explore the role green space plays in improving mental health, particularly in light of conflicting and negative associations with some physical health outcomes. Given that deprived neighbourhoods have been demonstrated to have relatively good access to green space in New Zealand, future work should focus on the role that quality of these spaces and the surrounding neighbourhood environment, along with measures of private green space. Such work could incorporate potential barriers to using recreational amenities, such as fear and safety, particularly around age, and gender and ethnic preferences.

Exposure to air pollution

Air pollution and health has been a long established area of research in the GeoHealth Laboratory, research outputs have included a series of reviews and commentaries that contribute both to local (Kingham, 2011; Kingham and Dorset, 2011) and international (Wilson *et al.*, 2005; Wilson *et al.*, 2006) understanding of air quality and health issues. The research projects have included a series of papers that would broadly be classified as environmental epidemiology. This includes work that has attempted to assess population exposure to poor quality air both spatially (Kingham *et al.*, 2008) and temporally (Kingham *et al.*, 2006). The results of this work have then been used

to relate to various spatial (Kingham et al., 2008) and temporal (Cavanagh et al., 2006; Epton et al., 2008) health outcomes while a further temporal analysis paper included the air quality methods within the health paper from Wilson et al. (2010). Rarely are relationships between air quality and health straightforward with a range of confounders and challenging methodological issues. Some of these have been the specific focus of research including a study by Sabel et al. (2007) that examined the role of confounders within an intra-urban context and Fukuda et al. (2010) which found that the effect of spatial variation in air pollution on adverse health outcomes in winter can be identified more accurately if viral infection data is accounted for.

Inequalities in exposure to air pollution and rates of related health outcomes have become increasingly polarised in New Zealand over the past 25 years with lower socioeconomic neighbourhoods tending to have higher rates of air pollution related illness compared to more affluent areas. However, research suggests that these areas may suffer a disproportionate burden of harm. This theme of environmental justice has been applied in air pollution research, with studies increasingly showing that neighbourhoods with the most sources of emission have the lowest levels of pollution Kingham *et al.* (2007).

Pearce *et al.* (2006) suggest four reasons why environmental harm is unequally distributed spatially throughout the population. First, low socioeconomic groups may have a lower overall demand for environmental quality; second, disadvantaged groups tend to be less educated and less aware of the potentially adverse effects; third, disadvantaged communities lack the social cohesion to resist corporate and political influences; and last, institutional discrimination may have influence over the location of pollution sources. From within this framework, Pearce *et al.* (2006; 2007) examined social and geographic inequities in domestic heating-related air pollution in Christchurch, New Zealand. In these studies, the most deprived neighbourhoods suffered more than areas of average to high socioeconomic status. In addition, air pollution levels were significantly lower in areas with more domestic wood burners. The effects of the inequality in the distribution of air pollution are exacerbated by the fact that individuals living in areas with the greatest exposure (low socioeconomic status) are predisposed to be vulnerable to the health effects of air pollution because of underlying health conditions, more barriers in access to healthcare, and poor housing conditions. Following these studies, Kingham *et al.* (2007) examined inequalities in exposure to vehicle related air pollution in

Christchurch. Like sources of domestic heating, the most deprived neighbourhoods had 1.5-2.0 times more vehicle related air pollution compared to more affluent areas. Areas with the highest level of vehicle ownership had the lowest levels of vehicle pollution, suggesting that those responsible for producing the most suffer the least.

With social and geographic inequalities in air pollution sources and exposure well documented, Richardson *et al.* (2011) studied this association by comparing air pollution levels and associated respiratory illness in New Zealand. The authors examined if air pollution is associated with respiratory disease mortality, and if individuals living in low socioeconomic areas suffer a greater predisposition to air pollution exposure. Richardson *et al.* (2011) found that exposure to air pollution was associated with respiratory disease mortality, as areas with the highest levels of air pollution had an 18% greater risk of respiratory disease mortality compared to areas with the lowest levels of exposure. Significant inequalities in respiratory disease mortality existed between low and high socioeconomic areas, however the role of socioeconomic status was not a significant modifier in the relationship between mortality and pollution. This study suggests that disadvantaged communities are not more susceptible to the effects of air pollution, but they do suffer a greater burden pollution related disease. In order for air pollution related health inequalities to be reduced, initiatives to reduce air pollution levels must be targeted towards achieving reductions in low socioeconomic areas.

Inequalities in access to and utilisation of health services

Patterns of inequality of healthcare utilisation were highlighted by Barnett and Lauer (2003) in their study of neighbourhood deprivation and hospital admissions in Christchurch for the period 1990-1997. The authors found that total admission rates rose during the study period, however there was evidence of social polarization in their results. The likelihood of hospitalisation for individuals living in the most deprived, compared the least deprived neighbourhoods, rose from 1.67:1 in 1990 to 2.21 in 1997. The socioeconomic gradient in admissions changed markedly as well: for every one decile unit rise in deprivation in 1990, hospital admission rates rose by 2.86/1,000 people. By 1997, this had increased to 7.38/1,000. Socioeconomic polarisation in multiple admissions increased during the study period also. The rate of admission from

the most deprived neighbourhoods was 3.26 times higher than from the least deprived neighbourhoods in 1997, compared to 1990.

There was evidence of inequalities in length of stay between groups, with patients from the most deprived neighbourhoods staying, on average, 6.5% or 0.34 fewer days than individuals from the least deprived. A lower length of stay is likely to be reflective of poorer quality of care, and this may result in higher readmission rates. The authors found evidence that readmission was higher among more deprived groups and that there was a widening of the gap between deprived and affluent neighbourhoods over time. In 1990, an increase of one decile of neighbourhood deprivation was associated with an increase in readmission rates of 1.16/1,000. By 1997, this had risen to 3.77/1,000. Just as lower length of stay may result in higher readmission rates, these high rates may in turn lead to pressure on bed space and force higher turnover of patients. It is possible that individuals with particular illnesses may be more likely to be discharged sooner, and there was evidence in this study of differences between socioeconomic groups in the causes of admission. Individuals from the most deprived areas were more likely to be readmitted with asthma and other respiratory diseases, chronic airway obstruction, and pneumonia, while the least deprived patients were more likely to be readmitted for ongoing treatment of various forms of heart disease.

Barnett and Barnett (2004) subsequently examined the role of socioeconomic status in utilisation of general practitioners (GPs), the main source of primary care in New Zealand. Unlike many hospital admissions, there is a cost associated with consultation and treatment from GPs. This is believed to be significant enough to deter individuals, particularly from low socioeconomic groups, from seeking prompt and adequate care. The financial barrier that GP fees present for some people may increase pressure on hospital services, with avoidable admissions tying up resources that should otherwise be treated in a GP setting. The authors found that patients who are faced with financial difficulties were more likely to delay seeking care and medication, and were also more likely to seek financial help from their GP. From a practice setting, GPs in deprived neighbourhoods were more likely to charge lower fees than those in affluent areas, however they were generally less flexible in the provision of financial options to patients. Beyond direct costs to GPs, Barnett and Barnett (2004) cited direct correlations between distance and the utilisation of GP and hospital services. There is also evidence of an undersupply of GPs

located in low socioeconomic neighbourhoods, and an oversupply in more affluent areas. Individual perceptions of access to care in deprived, high need areas are likely to be low if there is significant travel distance required and few providers serving the population.

The effect of neighbourhood access to GPs was further explored by Hiscock *et al.* (2008) to determine if travel time is a predictor of utilisation and patient satisfaction. Residents living in neighbourhoods with the longest travel time to GPs were less likely to have visited a GP in the previous year (Odds Ratio 0.74). However, this relationship was present only in rural and secondary urban areas, with no relationship in urban areas after adjustment. There was no evidence that travel time was associated with healthcare service satisfaction, and as the relationship with utilisation was not consistent, the authors concluded that access to GPs could not explain health inequalities in New Zealand. The association with travel time and utilisation in rural communities should also be set within the wider challenges faced by health care providers serving rural communities that cover large geographic areas and that correspondingly have isolated residents.

Brewer *et al.* (2012) set their analysis of access to healthcare services in the context of travel time and distance to services and inequalities between ethnic groups in cervical cancer diagnosis and mortality trends in New Zealand. Previously in New Zealand, marked ethnic inequalities in cervical cancer incidence and mortality have been found, with Māori and Pacific women at higher risk compared to European women (Ministry of Health, 2010). Māori and Pacific women were also comparatively under-screened (Smith *et al.*, 2011), and there is evidence of large differences between groups in the stage of cervical cancer at diagnosis (Brewer *et al.*, 2009). This study found weak associations between travel time/distance and cervical cancer screening, stage at diagnosis, and mortality among New Zealand women. The primary effects of travel time, though weak, were associated with ethnic variation in cervical cancer stage at diagnosis but not the subsequent survival rates.

Beyond the GeoHealth Laboratory: spatial health data and research in New Zealand

The previously discussed indices and measurements of access to neighbourhood resources and subsequent population level health outcomes and behaviours have set the scene for research focused at smaller spatial scales. Aggregated datasets have been useful in identifying potential health promoters or barriers in the

natural and urban environment however the underlying causal pathways cannot be fully understood using these methods. Emerging research has begun to focus on how individuals interact with their physical environment on a daily basis to examine how behaviours and perceptions of residents vary between and within neighbourhoods. A large aspect of this work has been raw data collection to better understand and explain the processes of interest and answer more specific research questions that have developed out of previous work, such as that discussed in this article, that has been largely ecological in nature. Two major goals are clear from this data collection and research: to better inform policy makers and provide benefits to local communities through tangible solutions and outcomes.

Spatial health data

Health data in New Zealand is collected at a local (practitioner), regional (District Health Board (DHB)), and national level, however, most primary care services are private and are not under statute to provide data for national collection. Data for primary health care services can be sought directly through DHBs or through local health care providers: Public Health Organizations (PHOs). DHBs are funded and monitored by the MOH and this provides the basis for collection of data at a national level. The MOH collects individual records for hospital inpatients and non-admitted hospital patients (e.g. Emergency presentations), laboratory tests conducted, prescriptions collected, and primary care enrolment. In addition to this core data the MOH also collects data on directly funded services (e.g. telephone lines, national initiatives (immunization, well-child checks) and pilot schemes).

Almost all individual health data collected centrally has a unique identifier attached to it, known as the National Health Index (NHI), and a spatial component, meshblock of domicile. Having the NHI means that datasets can easily be joined together and used to form supplementary, enhanced information. For example a virtual diabetes register has been made using laboratory, hospital and pharmaceutical records.

Lastly, the MOH conducts a continuous, National Health Survey, which consists of a set of core questions combined with a flexible programme of rotating topic areas/modules – for example health surface utilization (Ministry of Health, 2013). The survey is rich in robust data which cannot be collected elsewhere, for example information on weight, exercise, Health service utilization and health behaviours. Survey data can be linked to geography

through the respondents Meshblocks or domicile and it is this ability that has enabled the development of indices of access to factors in the built environment.

Neighbourhoods and health research groups

The University of Otago's Department of Public Health is a major contributor in the field of neighbourhood effects on health. The Neighbourhoods and Health project, running since 2004, has focused on measuring community resources and both social cohesion and social fragmentation to examine the association with morbidity and mortality. This has been achieved through analysis of existing data as well as the collection of new information (University of Otago, 2013). Alongside this work is He Kainga Oranga, the Housing and Health research programme. Links to ill-health as a result of poor housing stock are well known in a New Zealand context however the causal pathway of this relationship is not well understood. The multi-disciplinary research team working on this project is furthering knowledge in this field and has a strong policy focus. By utilizing existing data and carrying out new studies they aim to introduce housing-related interventions that will improve the health of individuals, families, communities and the population as a whole (University of Otago, 2013).

The New Zealand Centre for Sustainable Cities has brought together multi-disciplinary experts, including current and ex-GeoHealth staff, to investigate solutions that provide for cities that a built foundations of resilience, live-ability and competitiveness. There are a number of core project strands in their Resilient Urban Features Programme that cover urban change and development, community form and social development, infrastructure and transportation, environmental exposures and effects. This work has a strong focus on policy outcomes and has experimented with local trials, such as rental housing Warrant of Fitness and cycleways, to better realize the opportunity for wider implementation. Funding is provided by the Ministry of Business, Innovation and Employment (Centre for Sustainable Cities, 2013).

SHORE, based at Massey University, undertakes research spread across a range of health and social topics. Neighbourhood determinants of health and wellbeing and sustainable cities are two key themes of this research. Access to tobacco, alcohol and gambling opportunities at a community level and the associated behaviours and health outcomes have also received attention from this group. This research draws on qualitative and quantitative techniques to

inform policy makers and carry out community based research (Massey University, 2013).

Concluding remarks in light of current health sector priorities

The Geohealth Laboratory work reviewed in this article represent research priorities relating to neighbourhood access to factors in the built environment that can affect health outcomes, demonstrating the wide range of research that we have done in this space. Although overseen by and aligned to the current priorities and objectives of the Ministry of Health, the GeoHealth Laboratory remains a status as an independent research entity. As a consequence, a number of publications have generated sector and media interest and debate (Todd, 2011). In the context of the current health sector there are several debates that our work has been able to contribute to.

First, work outlined in the inequalities in factors of the built neighbourhood environment section has contributed to debates relating to the degree to which government control over health behaviour should take precedence over personal choice.. For example, left uncontrolled we have shown fast-food, tobacco and alcohol outlets are more likely to locate next to deprived areas than next to affluent areas. Recently, the New Zealand Burden of Disease study, a systematic analysis of health loss by cause for New Zealanders, highlighted key risk factors for health loss i.e. poor health (Ministry of Health, 2013), among these were substance use (tobacco, alcohol and illicit drugs) and dietary risk factors.

Second, research by the GeoHealth Laboratory relating to the equity/efficiency models of health service provision has provided evidence of the inequalities in access to, and utilisation of, health services. We have shown that an undersupply of health services in deprived neighbourhoods, significant travel distances, and financial barriers, whether perceived or real (co-payments have largely reduced costs to zero for low SES groups) all affect health service use by deprived groups (Hiscock et al., 2008). This was confirmed recently by the New Zealand Health survey which showed that rates of unmet need were higher in deprived areas (Ministry of Health, 2012). Undertaking work of this nature has helped to inform policy for delivering health services ‘closer to home’ in an economic climate where health funding has focused on centralised, co-located services.

Lastly, it should be noted that New Zealand is not unique in experiencing the health issues identified above. For instance, the recent global burden of disease study highlighted an increase in non-communicable diseases such as ischemic heart disease and diabetes, and a shift towards disabling causes rather than fatal causes in developed countries. This is mainly due to population aging and to a lesser extent, population growth. In Australia, New Zealand, Japan, and richer countries in Western Europe and North America, health loss for non-communicable diseases contributed to more than 80% of all health loss (IHME, 2013). Thus our research is applicable to and has influences wider than just New Zealand, but can be applied globally.

There is still a significant amount of research to undertake. The geospatial and health landscape is constantly changing. New health priorities, further improvements in health data quality, and new technologies in GIS, are all allowing us to progress research which hitherto, was never possible. The New Zealand Burden of Disease study, which highlighted some recent major areas of health concern such as cancer, vascular and blood, and mental disorders, coupled with rising health care costs and the need for better local regional and national planning, is fuelling recognition of the importance of geospatial research. The continuous New Zealand Health survey, previously held every four years (and annually since 2011), allows the opportunity to explore robust spatial data on specific topics such as patient choices and health behaviours over time. Health sector-wide geocoding of patient addresses at point of entry will improve the accuracy of administrative health data and improve the confidence of results. Further, sophisticated geographical techniques such as spatial micro simulation (Campbell and Ballas, 2013), hill shading (Llobera, 2003), can be juxtaposed against simple online applications to display and disseminate research results, making a wide range of data available to policy and decision makers.

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