Associations between urban characteristics and non-communicable diseases

Rapid evidence review

Canterbury
District Health Board
Te Poari Hauora ō Waitaha

Prepared for the Health in All Policies Team
by the Information Team
Community & Public Health
October 2016

Executive summary

Background

In Aotearoa New Zealand, non-communicable diseases (NCDs) are the leading cause of health loss and contribute to significant inequities. As many of the risk factors for NCDs are modifiable to some extent, there is substantial opportunity for NCD prevention through effective population health interventions. The physical (natural and built) and social environment are determinants of health with the potential to impact health and equity through influencing behaviour and safety. As the majority of the New Zealand population lives in urban areas, creating urban environments that support health will impact a large number of people.

Methods

This rapid evidence review presents recently-published literature relating to the associations between urban characteristics and modifiable risk factors for NCDs (physical inactivity, obesity, high blood pressure and blood cholesterol, and alcohol and tobacco use) and the NCDs that contribute the greatest health loss (coronary heart disease, anxiety and depressive disorders, stroke, chronic obstructive pulmonary disease, type 2 diabetes mellitus, cancers, and arthritis). It also considers the impacts of urban interventions on health, and the relevance of these findings to New Zealand.

Several limitations must be taken into account when interpreting the findings of this review. Firstly, the majority of studies included in this review use a cross-sectional design, which means that causal inferences cannot be made. It is also important to consider the potential for confounding, where the effect of exposure to certain urban characteristics on a health outcome could be due to other factors that influence the health outcome. Studies were also highly heterogeneous in their characteristics (including population, location, and definitions and measures of urban characteristics and health-related outcomes), which made summarising the evidence particularly challenging. Studies often focused on the relationship between a single environmental characteristic and one risk factor or disease, which does not acknowledge the complex interactions between urban attributes and how these in combination may impact the health of residents. The extrapolation of findings from other high-income countries to a New Zealand setting may be limited due to differences in urban environments. Finally, this review has been carried out in a short timeframe and is not, and does not claim to be, comprehensive or systematic.

Findings

There is a large body of literature investigating associations between urban characteristics and health. Overall, evidence from recent reviews suggests that the associations between NCD risk factors and urban characteristics are inconsistent, likely in part due to the heterogeneity of studies. However, some neighbourhood characteristics that are most consistently associated with decreased NCD risk factors include greater green space, walkability, access to resources and amenities, residential density, land-use mix, social capital, places for social interaction, socioeconomic advantage, walking and cycling infrastructure, and environment quality and aesthetics; and low air and noise pollution, traffic speed and volume, and density of alcohol and tobacco outlets. In addition, there is some evidence of significant associations between a lower prevalence/incidence of selected NCDs and greater green space, walkability and aspects of urban compactness; and lower air and noise pollution, socioeconomic deprivation, and perceived stressors (e.g. fear, cohesion, and aesthetics). Interventions to improve the urban environment (particularly active transport infrastructure and green space improvements) can potentially contribute to more physical activity among local residents.

In New Zealand, greater neighbourhood socioeconomic deprivation is often associated with significantly poorer health outcomes among residents. It has been suggested that factors such as the distribution of neighbourhood resources and exposure to stressors (such as traffic noise and air pollution) may contribute to these inequities. While there does seem to be more “unhealthy” exposures (such as alcohol, tobacco and fast food outlets) in more disadvantaged areas, these areas also have more health-promoting community resources (such as public open/green and recreational spaces, marae, health facilities, education providers and supermarkets) overall. However, the quality and accessibility of the health-promoting resources in these areas, a factor not often studied, is an important consideration when looking at the influence of the local environment on health. Studies exploring the relationship between New Zealand urban characteristics and physical activity, body weight, alcohol and tobacco use, cardiovascular disease, and depression and anxiety tend to be in agreement with international evidence.

Conclusions

Evidence indicates that aspects of the physical and social environment that enable movement, provide destinations, and enhance day-to-day experiences in the urban setting, are associated with modestly improved NCD risk factors, and lower risk of some NCDs. Further, urban environments that incorporate these features are likely to be more equitable and inclusive. While this review has only considered the impact of the urban environment on a selection of NCD risk factors and outcomes, there are many potential environmental, economic and other health co-benefits of designing urban areas that support reduced NCD morbidity.

As the identified health-promoting urban characteristics are modifiable to varying degrees, this creates an opportunity for intervention – either when upgrading existing areas or creating new spaces. Translating evidence into policy and practice is challenging and creating healthy urban environments requires the involvement of sectors beyond those responsible for health. Using Health Impact Assessment within a Health in All Policies approach can assist with creating healthy urban environments through integrated planning – utilising collaborative approaches across the public and private sectors, and levels of government.

The application of health-promoting urban design is particularly pertinent in Canterbury, where significant reconstruction is underway after the devastating earthquakes in 2010 and 2011. There is still great opportunity to further upgrade and develop medium-density, mixed-use, mixed-income neighbourhoods that are attractive, safe and sociable to promote good health for all Cantabrians. This reconstruction also provides an ideal space to use pilot projects to trial new urban interventions that are sensitive to local circumstances which can be evaluated to further inform urban policy and planning in other parts of New Zealand.

Table of contents

Background

Health burden of non-communicable diseases in Aotearoa New Zealand

In Aotearoa New Zealand, non-communicable diseases (NCDs) are the leading causes of health loss (i.e. early death, illness or disability), particularly coronary heart disease (CHD), mental disorders, type 2 diabetes mellitus (T2DM), and cancers (Ministry of Health, 2013). In addition, there are significant NCD-related inequities between Māori and non-Māori. Several high-priority risk factors have been identified that contribute substantially to the burden of NCDs and inequities in New Zealand. These include tobacco and alcohol use, obesity, high blood pressure and cholesterol, and physical inactivity (Ministry of Health, 2013; Wilson et al., 2012). As these risk factors are modifiable to some extent, there is substantial opportunity for NCD prevention through effective population health interventions.

The role of the urban environment in population health

The physical (natural and built) and social environment are determinants of health that interact in complex ways to impact population health through their influence on behaviour and safety (Commission on Social Determinants of Health, 2008; Marmot et al., 2008; Rydin et al., 2012; Sallis et al., 2006) (**Figure 1**). As the majority of the New Zealand population lives in urban areas (Statistics New Zealand, 2006), creating urban physical and social environments that support health will impact a large number of people.

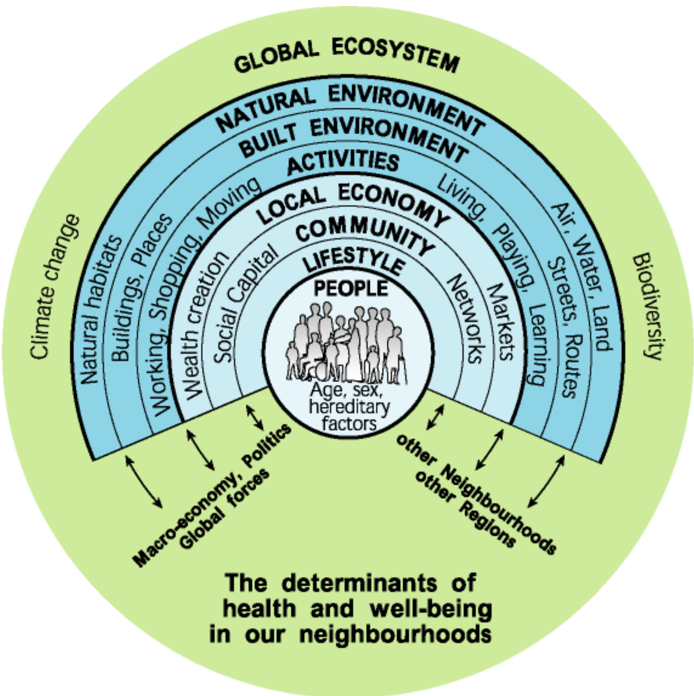

Figure 1. Health map showing the relationships between the determinants of health and wellbeing (Barton & Grant, 2006).

There is a strong ethical case for creating health-promoting urban environments (Sainsbury, 2013), and urban planning and design could contribute to health equity (Commission on Social Determinants of Health, 2008; Marmot et al., 2008). Environmental approaches to enable healthy behaviours are essential as individual-level interventions alone are consistently found to be less effective, and may contribute to further increasing health inequities as those with more resources are better able to implement the suggested behaviours (Backholer et al., 2014; Beauchamp et al., 2014; Lorenc et al., 2013).

There are many neighbourhood-level characteristics of the physical and social urban environment that have been studied in relation to their potential effects on health (**Figure 2**). This review will consider these characteristics' association with NCDs that contribute the greatest health loss in New Zealand (CHD, anxiety and depressive disorders, stroke, chronic obstructive pulmonary disorder (COPD), T2DM, cancers, and arthritis), and the main modifiable risk factors (physical inactivity, overweight and obesity, high blood pressure, high blood cholesterol, alcohol use, and tobacco use).

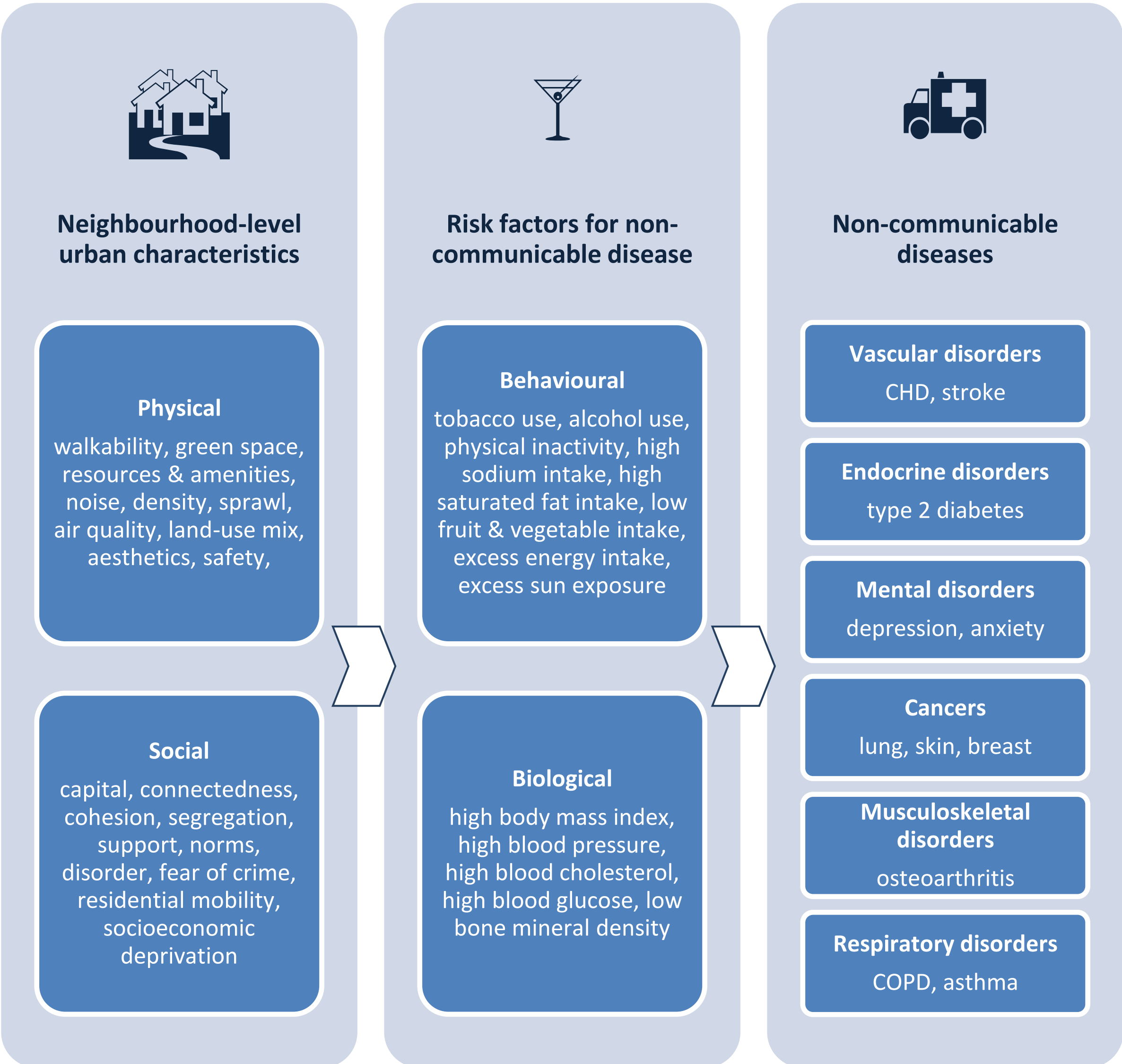

Figure 2. Examples of neighbourhood-level urban characteristics that could potentially influence several NCD risk factors and morbidity.

Methods

This rapid evidence review has been prepared in response to a request from the Health in All Policies Team (Community & Public Health), and presents findings on:

1. the associations between urban characteristics and risk factors for non-communicable diseases
2. the associations between urban characteristics and the prevalence and incidence of non-communicable diseases
3. the outcomes of urban design interventions on health, and
4. the relevance of these findings to Aotearoa New Zealand.

The information gathered will provide a resource for the team and inform their work preparing position statements, presentations, and submissions.

Literature search

A literature search to identify English-language peer-reviewed journal articles published between January 2010 and March 2016, was conducted via Medline (OVID), using a combination of the Medical Subject Heading (MeSH) search terms:

- exp environment design/ OR exp city planning/ AND
- exp chronic disease/ pc [prevention & control] OR
- exp diabetes mellitus/ ep,pc [epidemiology, prevention & control] OR
- exp cardiovascular diseases/ ep,pc OR
- exp obesity/ ep,pc OR
- exp mental health/ OR
- exp arthritis, rheumatoid/ or exp arthritis OR
- exp risk factors/ OR
- exp New Zealand/

A separate search for studies undertaken in New Zealand was also included, using nzresearch.org.nz. To source systematic reviews and meta-analyses, a search was also conducted via the Cochrane Library, using the MeSH search terms:

- environment design OR
- city planning

A broad search was also conducted using both Google Scholar and Google, and various combinations of the search terms listed above, to identify further published and grey literature. Titles and abstracts of publications extracted from the search strategies above were assessed for relevance. Further, the reference lists of relevant publications were hand-searched to identify further literature. Studies which specifically focused on low-income countries were not included in the evidence review due to the potentially limited applicability to a New Zealand urban setting.

Limitations

When considering the findings presented, it is important to keep in mind the limitations of this rapid evidence review.

Hierarchy of evidence

There is an increasing body of literature investigating associations between the urban environment and health outcomes, mostly using observational study designs. While factors that are associated with rates of disease at a population level may not necessarily be associated with disease among individuals (known as the "ecological fallacy"), population-level studies play an important role in generating hypotheses of the potential causes of disease (Pearce, 2000). In addition, some disease risk factors do operate at the population level where "they may cause disease as effect modifiers or determinants of exposure to individual level risk factors" (Pearce, 2000).

Most of the studies of the urban environment and health to date have used cross-sectional study designs. As cross-sectional studies assess environmental characteristics and health outcomes often at a single point in time, it is not possible to determine causation (Coggon, Rose, & Barker, 2003; Mann, 2003) - that is, whether the environment influences people's behaviour/health, or whether people with specific behaviours or health status reside in certain environments based on their needs, abilities and preferences (Diez Roux & Mair, 2010). Longitudinal studies are better able to establish causality as they follow individuals over time and can measure changes in both environmental variables and health outcomes (Coggon et al., 2003; Mann, 2003).

In these types of studies it is difficult to control for all of the factors that may influence health outcomes for those who live in environments with different characteristics. These factors (confounding variables) are independently associated with both the urban characteristic of interest and the health outcome (Mann, 2003). For example, a low prevalence of COPD among people living near the beach may not necessarily be due to the coastal environment, but may be due to a higher proportion of younger people living in those particular areas. Therefore, adjustments in the analyses can be made for suspected confounding factors, such as age (Coggon et al., 2003). In studies investigating the urban environment and health it is particularly important to consider socioeconomic factors as these can influence, or be influenced by, geographic patterns of resources and residence. Not including individual-level socioeconomic factors in analyses may "inflate" effects seen at the neighbourhood level, and prevent the "disentanglement" of the relative contributions of socioeconomic measures at the individual and neighbourhood levels (Rachele, Giles-Corti, & Turrell, 2016). Accounting for neighbourhood socioeconomic deprivation is also important, as relatively deprived New Zealand neighbourhoods tend to have better street connectivity, greater dwelling density, and better access to some destinations (Ivory et al., 2015a). In some studies included in this review both unadjusted and adjusted results (for various potential confounders) were presented, however, only adjusted results are reported here. For further detail on factors included in the adjusted analyses, please refer to the tables in Appendix A and/or the original published articles (listed in the References section).

Rigorous intervention studies are required to determine the effect of environmental characteristics on health outcomes. However, true randomised controlled trials are not often possible in urban environment research due to the large-scale and complex nature of the interventions, lack of suitable control groups, ethical considerations, and the inability to randomise or blind participants to their group allocation. Therefore it is useful to take advantage of “natural experiments” and quasi-experiments whenever available (Diez Roux, 2007, 2016). These studies evaluate the outcomes of naturally-occurring urban interventions or policies (for example, the construction of a new city cycleway) which are not under the control of the researchers (Craig et al., 2011, 2012). However, natural experiments are susceptible to bias and confounding, therefore caution is needed when interpreting evidence from these types of studies (Craig et al., 2011, 2012).

Analysing complex systems

There are several limitations in the methods used to analyse relationships between aspects of the urban environment and residents’ health (Diez Roux et al., 2010). These are largely due to the complex nature of urban systems, meaning that “simple causal relations between dependent and independent factors are difficult to isolate” (Rydin et al., 2012). Studies often focus on the relationship between a single environmental characteristic in isolation and one risk factor or health outcome – such as fast food outlet density and body mass index (BMI) (Feng et al., 2010; Freedman, Grafova, & Rogowski, 2011; Leal & Chaix, 2011). However this does not acknowledge the many interactions between urban attributes and how these in combination may impact the health of residents. It also does not recognise the multi-causal and long-term nature of NCD development. See **Figure 3** for a pictorial example of just some of the connections between the urban environment and health outcomes (Rydin et al., 2012).

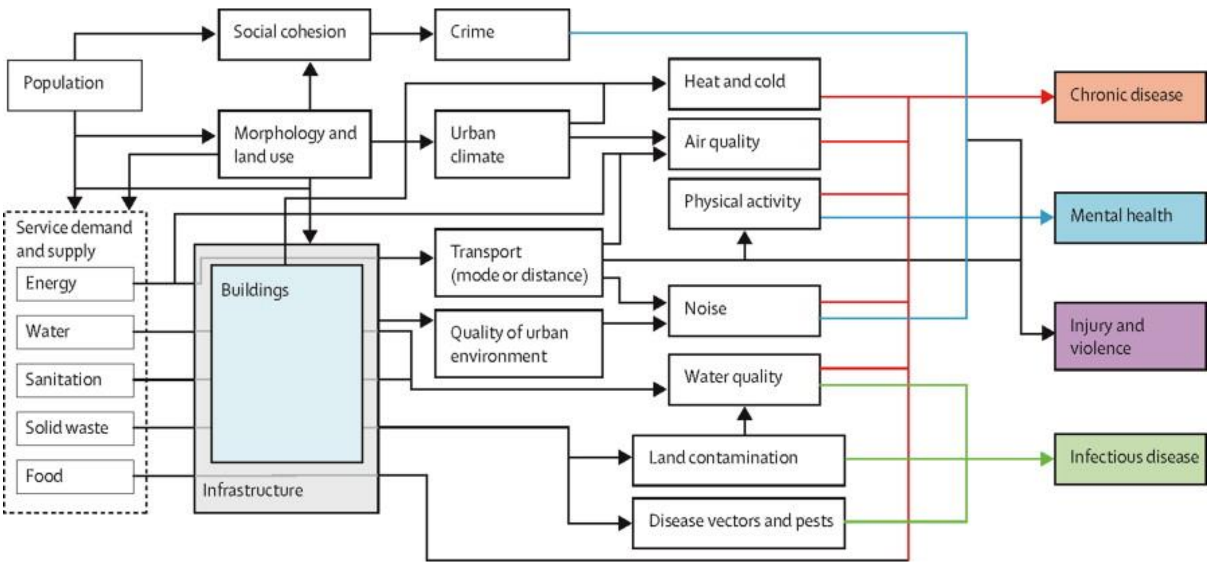

Figure 3. Health outcomes and the urban environment: connections (Rydin et al., 2012).

In addition, there is considerable heterogeneity across studies in the way environmental features are defined and assessed, where the many measures used describe slightly different aspects of the same construct (Diez Roux et al., 2010). This means that findings on a particular urban characteristic may appear inconsistent. For example, access to unhealthy food outlets has been assessed in many ways, including the distance to the nearest outlet from home, the number of outlets within a specified radius of a school, the density of outlets within an area, the ratio of unhealthy to healthy outlets, travel time to the nearest outlet, and the perceived availability of unhealthy (or healthy) food in a neighbourhood. Even the definition of a “healthy” or “unhealthy” food outlet or a “neighbourhood” can vary considerably between studies. Measures of urban characteristics often focus on the immediate area around the home, however consideration of other environments where people spend a significant proportion of their time, such as work and education settings, is needed (Koohsari et al., 2015).

It is also challenging to measure how people interact with their physical and social environments in their day-to-day lives (Lee & Maheswaran, 2011). Therefore, it is important to consider both objective and subjective aspects of the urban environment. For example, while geographical proximity to healthy food outlets (assessed using Geographical Information Systems, GIS) may be a potential factor in the purchasing of healthy foods, survey-based measures of the perceived food environment may incorporate the consideration of other factors, such as food affordability and quality, that will also influence purchasing behaviour (Christine et al., 2015).

Generalisability to Aotearoa New Zealand

Much of the evidence included in this review is from the United States of America (USA), Canada, Europe, Australia and the United Kingdom (UK). Built environment features, such as residential density, park density, and walkability, can vary widely between countries (Adams et al., 2014). Therefore, the extrapolation of findings from other high-income countries to a New Zealand setting may be limited due to differences in the environment, such as lower population density, lower public transport density, and a relatively high percentage of green and blue (aquatic) space, in urban areas in New Zealand. Therefore, the conclusions made must be interpreted acknowledging that they may not be entirely comparable with the New Zealand situation.

Finally, this review has been carried out in a short timeframe and has accessed literature using databases readily available to the Canterbury District Health Board. It is not, and does not claim to be, comprehensive or systematic.

Findings

Associations between urban characteristics and risk factors for non-communicable diseases

There is a very large body of literature investigating associations between various urban characteristics and risk factors for NCDs. Therefore, recent reviews (where possible) were used to summarise the evidence for several high-priority risk factors for NCDs. The heterogeneity of study characteristics (including population, location, and ways of defining and measuring urban characteristics and health-related outcomes) was often noted in the reviews, and made summarising the evidence particularly challenging.

Physical inactivity

Features of the urban environment can both facilitate and constrain physical activity. Several recent reviews have investigated the association between numerous urban characteristics and different aspects of physical activity across the lifespan. Physical activity measures included total activity, leisure activity, walking and/or cycling for transport or recreation, and moderate-to-vigorous activity, and were assessed using a range of self-reported and objective measures.

In general, the urban features most commonly reported to be significantly associated with higher levels of physical activity (particularly walking) among adults included: better access to neighbourhood **green space,** greater **walkability** (an indicator of how conducive an area is to walking)**,** better **access to retail/services/work destinations,** higher **urban density,** more **walking and cycling facilities/infrastructure,** greater **land-use mix** (where a range of residential, commercial, cultural, industrial and recreational land uses are integrated), and higher **environment quality** (Cooper, Boyko, & Cooper, 2011; Durand et al., 2011; Giles-Corti et al., 2014; Grasser et al., 2013; Kent, Thompson, & Jalaludin, 2011; Lachowycz & Jones, 2011; Lee et al., 2011; McCormack & Shiell, 2011; National Institute for Health and Care Excellence, 2008; Renalds, Smith, & Hale, 2010; Sugiyama et al., 2012; Van Holle et al., 2012; Wang et al., 2016; Zapata-Diomedi, Brown, & Veerman, 2015). However, findings from studies included in the reviews were often mixed (i.e. for the same urban characteristic, some studies showed statistically significant associations with physical activity, others no significant association, and some associations were only significant among particular sub-groups). Associations of many neighbourhood features tended to differ by country (Ding et al., 2013). When studies specifically focussing on the physical activity of older adults were reviewed, associations with urban characteristics were also inconsistent (Haselwandter et al., 2015; Van Cauwenberg et al., 2011).

Reviews specifically collating studies including children and adolescents found that the urban characteristics most often significantly associated with higher levels of physical activity included greater neighbourhood **walkability,** low **traffic speed/volume,** better access to **green space,** better **access to recreation facilities,** greater **land-use mix,** higher **residential density,** and better **appearance** (Christian et al., 2015; de Vet, de Ridder, & de Wit, 2011; Ding et al., 2011; McCrorie, Fenton, & Ellaway, 2014; National Institute for Health and Care Excellence, 2008). Interestingly, a meta-analysis of 23 studies found that neighbourhoods with GIS-defined features that may promote play (e.g. recreation facilities, gyms, parks, playgrounds, beaches, sports venues, schools) and walking (e.g. footpaths, walking tracks, path lighting, traffic calming, traffic lights, high-connectivity streets and local destinations) had unexpected negative effects on children's objectively-measured moderate-to-vigorous activity, whereas there were small-to-moderate positive effects on adolescents' activity (McGrath, Hopkins, & Hinckson, 2015). It was suggested by the authors that parental concern about safety may contribute to the negative finding among younger children.

Few studies in these reviews used objectively-measured physical activity data, and those that did were less likely to find a positive relationship compared to those that used self-reported physical activity measures (Ding et al., 2011; Ferdinand et al., 2012). In addition, a higher number of significant associations were found among studies using objectively-measured (rather than subjective) neighbourhood characteristics (Ding et al., 2011). Due to the heterogeneity of studies included in the reviews, most considered only the significance of the associations between urban characteristics and physical activity, but were not able to determine the magnitude of the association (i.e. the size of the effect, say, in additional minutes of daily physical activity). In addition, almost all studies reviewed used cross-sectional designs, therefore the evidence is relatively weak.

Overall, evidence from several large reviews suggests that the associations between physical activity and urban characteristics are inconsistent, likely in part due to the heterogeneity of studies. However, some neighbourhood characteristics that are more consistently associated with greater physical activity (particularly walking) include better access to green space, greater walkability, better access to destinations, higher residential and urban density, greater land-use mix, more walking and cycling facilities/infrastructure, and better environment quality and aesthetics.

Overweight and obesity

In recent reviews, **urban sprawl, residential density, land-use mix** and **area socioeconomic position** were most consistently associated with BMI or overweight status among young people and adults, where less sprawl, greater land-use mix and density, and higher socioeconomic position were associated with a lower risk of being overweight or obese (De Bourdeaudhuij et al., 2015; Feng et al., 2010; Giles-Corti et al., 2014; Grasser et al., 2013; Leal et al., 2011; Mackenbach et al., 2014). It has been suggested that urban sprawl may decrease the availability of dietary and physical activity resources, and greater land-use mix and density may offer shorter distances between home, recreation, retail and work destinations (Mackenbach et al., 2014).

Mixed findings were noted for other urban characteristics, such as **green space** and the **food environment** (Cobb et al., 2015; Durand et al., 2011; Feng et al., 2010; Fleischhacker et al., 2011; Galvez, Pearl, & Yen, 2010; Gamba et al., 2015; Giskes et al., 2011; Kent et al., 2011; Lachowycz et al., 2011; Leal et al., 2011; Mackenbach et al., 2014; Renalds et al., 2010; Sallis et al., 2012; Williams et al., 2014). Several limitations have been identified that may contribute to the inconsistency of findings among studies of the urban food environment. These include using out-of-date or inaccurate datasets to identify food sources, categorising food sources based on general type as "healthy" or "unhealthy", including only a limited range of food sources (e.g. fast food outlets and supermarkets), considering food sources in isolation, assuming that food purchasing behaviours are restricted to the local neighbourhood, and defining exposure to food sources (Gamba et al., 2015; Gordon-Larsen, 2014; Lucan, 2015).

High blood pressure

Living in areas with higher levels of **air pollution** is associated with an increased incidence and prevalence of high blood pressure/hypertension (Giorgini et al., 2016). In addition, a systematic review including 27 studies found that greater **noise pollution, crime,** and **area deprivation,** and **areas less supportive of social interaction** were most often found to be significantly associated with hypertension (Leal et al., 2011). A review of several studies from Sweden also suggests that exposure to greater levels of **road traffic and aircraft noise** is associated with significantly increased risk of hypertension (Bluhm & Eriksson, 2011). In the studies included in these reviews, different measures of blood pressure/hypertension were used, including systolic and/or diastolic blood pressure as continuous outcomes, self-reported diagnosis of hypertension, other outcomes combining information on systolic/diastolic blood pressure exceeding different thresholds, and anti-hypertensive medication use.

The articles included in these latter two reviews were published prior to 2010, and since then, several related cross-sectional and longitudinal studies have been published. These studies found no significant association between hypertension and neighbourhood **walkability**, **public open space**, **immigrant population**, **crime** and **segregation**, **residential mobility** (moving between places of residence), **street connectivity**, or **density** (Coffee et al., 2013; Coulon, Wilson, & Egan, 2013; Freedman et al., 2011; Müller-Riemenschneider et al., 2013; Paquet et al., 2014). Findings were mixed for the **food environment**, **proximity to busy roads**, **pedestrian environment,** and neighbourhood **socioeconomic advantage** (Dubowitz et al., 2012; Freedman et al., 2011; Fuks et al., 2011; Lee, Mama, & Adamus-Leach, 2012; Paquet et al., 2014; Pindus, Orru, & Modig, 2015).

High blood cholesterol

Higher levels of **air** and **noise pollution,** and **area socioeconomic deprivation** were most often found to be significantly associated with dyslipidaemia (high blood cholesterol and/or triglycerides) in eight studies included in a systematic review (Leal et al., 2011). The articles included in this review were published prior to 2010, and since then, two studies conducted in Australia have been published that did not find any significant relationships between high blood cholesterol and **walkability**, **public open space**, or aspects of the **food environment** (Müller-Riemenschneider et al., 2013; Paquet et al., 2014).

Alcohol use

Reviews provide some evidence that higher **alcohol outlet density** and poorer **social capital** (community attachment, closeness, supportiveness and participation) may be associated with higher alcohol use among adults and adolescents, however findings were mixed depending on factors such as location and outlet type (Bryden et al., 2012; Bryden et al., 2013; Cooper et al., 2011; Gmel, Holmes, & Studer, 2016). No consistent significant associations were found between alcohol use and **distance to nearest alcohol outlet**, **exterior advertising** of alcoholic beverages, neighbourhood

socioeconomic disadvantage, **disorder** and **crime**, or **residential mobility** (Bryden et al., 2012; Bryden et al., 2013; Jackson, Denny, & Ameratunga, 2014; Karriker-Jaffe, 2011).

Tobacco use

Three elements of the local environment that could potentially influence smoking behaviour have been proposed: tobacco availability, which may influence community norms; social capital and practices that may reinforce smoking behaviours; and regulations/policies targeting the tobacco retail environment (Bowie et al., 2013). No reviews were sourced which investigated associations between the urban environment and tobacco use. However, several recently-published cross-sectional studies from New Zealand, Australia, Scotland and the USA have looked at access to tobacco retail outlets and smoking prevalence. Evidence suggests that greater **tobacco retail outlet density** in a neighbourhood is associated with higher rates of smoking among both adult and adolescent residents (Lipperman-Kreda, Grube, & Friend, 2012; Lipperman-Kreda et al., 2016; Lipperman-Kreda et al., 2014; Marashi-Pour et al., 2015; Pearce et al., 2016; Shortt et al., 2016). However, associations between current and experimental/trying smoking among adolescents and **tobacco retail outlet density near schools** were inconsistent in three studies (Lipperman-Kreda et al., 2014; Marsh et al., 2015; Shortt et al., 2016). When **distance to tobacco outlets** from home or school was considered, there was no significant association with smoking among adults (Pearce et al., 2009b) or adolescents (Lipperman-Kreda et al., 2014).

Summary

In summary, literature sourced for this review provides some evidence of associations between several physical and social neighbourhood-level urban characteristics and selected NCD risk factors (**Figure**). The characteristics listed below have been found to be significantly associated with some, but not all, risk factors considered in this rapid evidence review.

Figure 4. Urban characteristics most consistently associated with selected NCD risk factors (physical inactivity, overweight and obesity, high blood pressure, high blood cholesterol, alcohol use, and tobacco use).

Associations between urban characteristics and non-communicable diseases

The effect of some urban characteristics on the morbidity related to several NCDs with modifiable risk factors that contribute to significant health loss in New Zealand are presented here. Further details of the individual cross-sectional and longitudinal studies described in this section can be found in **Tables A1-A9,** and systematic reviews and meta-analyses in **Tables A10-A12** (Appendix A). These tables also include a list of individual- and/or neighbourhood-level factors that influence health (such as age, sex, weight, physical activity level, income, education, smoking status, socioeconomic deprivation) that were adjusted for in each study. Adjustment for these potentially confounding variables varies widely between studies, and it is important to consider whether residual confounding may explain some or part of the associations observed between urban characteristics and NCDs.

Type 2 diabetes mellitus

Green space

Three large cross-sectional studies conducted in the UK, Australia and The Netherlands have shown a significant inverse relationship between objectively-measured neighbourhood **green space** and, after controlling for multiple lifestyle and neighbourhood variables (Astell-Burt, Feng, & Kolt, 2014a; Bodicoat et al., 2014; Maas et al., 2009). Two studies found a lower prevalence of T2DM when green space was within 1 kilometre of the participant's home (Astell-Burt et al., 2014a; Maas et al., 2009), however only one of two studies assessing proximity within 3 kilometres of the participant's home found the association was significant (Bodicoat et al., 2014; Maas et al., 2009). This inconsistency in findings could be due to differences in the methods used to define proximity to green space, or differences in the potential for accessing these spaces. In addition, a longitudinal study in South Australia reported a significantly lower risk of developing pre-T2DM or T2DM with greater nearby **public open space** size (RR 0.75, 95% CI 0.69-0.83, p<0.0001), but not public open space number (p=0.93), greenness (p=0.89), or type (p=0.16) (Paquet et al., 2014).

Walkability

Four longitudinal studies provide relatively consistent evidence that living in more walkable neighbourhoods is associated with a lower risk of developing T2DM. Firstly, a study in Canada followed more than 1 million adults free of T2DM at baseline for 5 years (Booth et al., 2013). It found that the risk of developing T2DM increased significantly with decreasing neighbourhood **walkability** for both men and women, and more so for recent immigrants. For example, compared to long-term resident males living in the most walkable neighbourhoods, those living in the least walkable neighbourhoods had a 32 percent greater risk of developing T2DM (95% CI 1.26-1.38). For recent immigrant males, the risk was 58 percent greater for those living in the least walkable neighbourhoods (95% CI 1.42-1.75). The T2DM incidence rates were approximately twice as high in low-income areas, irrespective of the level of walkability.

Secondly, a significantly lower risk of developing T2DM was associated with higher **perceived walking environment availability** (HR 0.80, 95% CI 0.70-0.92) among 5,124 older adults in the USA followed over 10 years (Christine et al., 2015). Thirdly, **walkability** was also found to be associated with a significantly lower risk (RR 0.8, 95% CI 0.80-0.97, p=0.01) of developing pre-T2DM or T2DM in a study following 3,145 participants over an average of 3.5 years in South Australia (Paquet et al., 2014). Lastly, the incidence of T2DM among Canadian adults was lowest for those living in the most, compared to the least, **walkable neighbourhoods** (p=0.001) (Creatore et al., 2016). Between 2001 and 2012, incidence declined significantly in more walkable neighbourhoods (absolute change in adjusted annual incidence for quintile 5: −1.5, 95% CI −2.6 to −0.4 and quintile 4: −1.1, 95% CI −2.2 to −0.05), but not less walkable neighbourhoods (quintile 1: −0.65, 95% CI −1.65 to 0.39, quintile 2: −0.5, 95% CI −1.5 to 0.5, and quintile 3: −0.9, 95% CI −1.9 to 0.02).

However, there were no significant associations between the prevalence of self-reported T2DM and neighbourhood **walkability** within 800 metres (OR 0.79, 95% CI 0.52-1.21, p=0.282) or 1,600 metres of home (OR 1.08, 95% CI 0.72-1.62, p=0.701) in a cross-sectional study of 5,970 adults in Western Australia (Müller-Riemenschneider et al., 2013). In addition, living in more "**hilly**" areas in Western Australia was associated with significantly lower odds of self-reported T2DM in a cross-sectional study of 11,406 adults (Villanueva et al., 2013). Compared to those living in the least hilly areas, those living in moderately hilly areas had 28 percent lower odds of having T2DM (95% CI 0.55-0.95), and those living in the hilliest areas had 48 percent lower odds of having T2DM (95% CI 0.39-0.69). As the more hilly suburbs included in this study were typically more affluent, socioeconomic position could have been a potential confounder. Therefore, analyses were adjusted for individual-level income and education (two indicators of socioeconomic position). The authors suggest that a mechanism for the association between T2DM and neighbourhood hilliness could be the effect of hilliness on exercise intensity.

Air pollution

There is consistent evidence from several recent systematic reviews and meta-analyses of cross-sectional and cohort studies that longer-term exposure to higher levels of **outdoor air pollution** is associated with a modest but significantly higher risk of having, or developing, T2DM (Balti et al., 2014; Eze et al., 2015; Janghorbani, Momeni, & Mansourian, 2014; Park & Wang, 2014; Wang et al., 2014). Studies included in the reviews were mostly from the USA and Europe, and the air pollutants included gaseous pollutants associated with traffic (e.g. nitrogen dioxide) and/or particulate matter (e.g. $PM_{2.5}$, PM_{10}). Two reviews found that associations were more pronounced among females (Eze et al., 2015; Wang et al., 2014).

Food retail

Evidence of the relationship between T2DM and the **food environment** is mixed. In the first of two cross-sectional studies from the USA, the prevalence of T2DM was not significantly associated with the presence of nearby supermarkets (PR 0.96, 95% CI 0.84-1.10), grocery stores (PR 1.11, 95% CI 0.99-1.24) or convenience stores (PR 0.98, 95% CI 0.86-1.12) among 10,763 adults (Morland, Diez Roux, & Wing, 2006). On the other hand, a greater **availability of fast food restaurants and convenience stores** relative to grocery stores and produce vendors near homes was associated with a significantly higher prevalence of self-reported T2DM in a telephone survey of more than 43,000 adults from California (California Center for Public Health Advocacy, 2008a, 2008b). Adults living in areas with the highest ratio of unhealthy to healthy food vendors were 24 percent more likely to have been diagnosed with T2DM than adults living in areas with the lowest ratio of unhealthy to healthy food vendors (95% CI not reported).

Two longitudinal studies mentioned previously also investigated the effect of different aspects of the nearby food environment on T2DM incidence. In South Australia, the relative **healthfulness of the food environment** was not significantly associated with incident pre-T2DM or T2DM (p=0.88) (Paquet et al., 2014). However, in the USA, a significantly lower risk of developing T2DM was associated with greater **access to healthy food** in the neighbourhood when measured using survey (i.e. availability of healthy food nearby; HR 0.88, 95% CI 0.78-0.98), but not GIS (i.e. proximity to supermarkets and fruit/vegetable markets; HR 1.01, 95% CI 0.96-1.07) data (Christine et al., 2015). This study highlights the use of different data collection methods which measure slightly different aspects of the same construct. The author suggests that survey-based measures of the local environment may incorporate other factors that influence behaviour, such as food affordability and quality, walkability, and aesthetics, as opposed to some GIS measures, which are concerned only with geographical proximity.

Recreation facilities

One longitudinal study following 5,124 older adults in the USA for 10 years found no significant association between developing T2DM and the density of commercial recreational establishments (e.g. facilities for dance, bowling, sports, and water activities) within 1,600 metres of home (HR 0.98, 95% CI 0.94-1.03) (Christine et al., 2015).

Neighbourhood deprivation and other features

Three longitudinal studies provide evidence that **neighbourhood deprivation** is related to T2DM incidence. Over a 10-year period, residents of the most disadvantaged neighbourhoods among 200 neighbourhoods selected for cross-sectional study in Brisbane were 1.8 times more likely to report having T2DM than those living in the least disadvantaged neighbourhoods (OR 1.81, 95% CI 1.15-2.83) (Rachele et al., 2016). In addition, residents of the most disadvantaged neighbourhoods were three times more likely to report having both CHD and T2DM (concurrently) than those living in the least disadvantaged neighbourhoods (OR 3.00, 95% CI 1.49-6.13). Similarly, over a 3-year period older adults were significantly more likely to be diagnosed with diabetes if they lived in the second-most deprived (OR 1.41, 95% CI 1.06-1.87) or most deprived (OR 1.51, 95% CI 1.09-2.09) neighbourhoods in North Staffordshire (Jordan et al., 2014).

T2DM incidence was also assessed in a quasi-experimental longitudinal study of 61,386 refugees who were assigned to live in areas of varying socioeconomic deprivation on arrival in Sweden between 1987 and 1992 (White et al., 2016). The odds of developing T2DM between 2002 and 2010 were significantly greater among those assigned to live in areas of moderate (OR 1.15, 95% CI 1.01-1.31) and high (OR 1.22, 95% CI 1.07-1.38) deprivation, compared to those assigned to live in areas of low deprivation. When further analyses were conducted in an effort to control for unmeasured confounders, compared to those in low-deprivation areas, risk of T2DM increased non-significantly by 0.44 percentage points (95% CI -0.42-1.30) among those in moderate-deprivation areas, and also non-significantly by 0.85 percentage points (95% CI -0.03-1.73) among those in high-deprivation areas. Risk of T2DM accumulated over time, where an additional 5 years spent in a high-deprivation neighbourhood (compared to a low-deprivation neighbourhood) was associated with a 9 percent increase in risk. Approximately half of the residents had moved from their assigned area after 10 years, however the analysis did not take into account this subsequent movement after initial placement.

The incidence of self-reported T2DM over 2 years was assessed among 11,472 older men and women in the USA in relation to several neighbourhood features (Freedman et al., 2011). There were no statistically significant relationships between the onset of T2DM and any of the following neighbourhood features: **economic advantage or disadvantage**, high **immigrant area**, high **crime** and more **segregation**, **residential stability**, **street connectivity**, or **density** (when adjusted for individual-level potentially confounding factors such as BMI, family history of T2DM, smoking, income, and education level). Another longitudinal study from the USA found that there was no significant association between incident T2DM and either perceived neighbourhood **social cohesion** (HR 1.00, 95% CI 0.89-1.11) or **safety** (HR 0.96, 95% CI 0.82-1.11) (Christine et al., 2015).

Cardiovascular disease

The term cardiovascular disease (CVD) is used to describe disorders of the heart and blood vessels, and includes CHD and stroke (World Health Organization, 2016). The studies included in this section examine some of these diseases separately, or in combination.

Green space

Three cross-sectional studies have looked at aspects of neighbourhood greenness and the prevalence of CVD-related morbidity, and found some significant associations. The annual prevalence of CHD and cardiac disease among patients from 195 general practices in The Netherlands was significantly lower among those living in areas with more **green space** within a 1 kilometre (CHD: OR 0.97, 95% CI 0.95-0.99 and cardiac disease: OR 0.98, 95% CI 0.97-0.99), but not 3 kilometre (CHD: OR 0.97, 95% CI 0.93-1.01 and cardiac disease: OR 1.00, 95% CI 0.93-1.01) radius of their home after adjustment for education level, work status and health insurance type (Maas et al., 2009). There was no significant association between stroke or brain haemorrhage and percentage of green space within either a 1 kilometre (OR 0.98, 95% CI 0.95-1.00) or 3 kilometre (OR 0.98, 95% CI 0.92-1.04) radius of home.

Further, the relationship between CHD or stroke and neighbourhood greenness - **variability in greenness** (an indicator of land-use mix) and **mean greenness** - was investigated in a cross-sectional sample of 11,404 adults in Western Australia (Pereira et al., 2012). The odds of hospital admission for CHD or stroke was significantly lower among adults living in areas with the highest variability in greenness (i.e. mixed land use areas), compared to those living in areas with the lowest variability in greenness (i.e. predominantly green, or predominantly non-green, neighbourhoods) (OR 0.63, 95% CI 0.43-0.92). For self-reported medical diagnosis of CHD or stroke, the odds were significantly lower among adults living in areas with moderate variability in greenness, compared to those living in areas with the lowest variability in greenness (OR 0.76, 95% CI 0.62-0.94), but the association was not significant when those with the highest and lowest variability in greenness were compared (OR 0.84, 95% CI 0.68-1.03). No significant associations were found between CHD or stroke and mean neighbourhood greenness, after adjustment for CHD and stroke risk factors (such as BMI, hypertension, high cholesterol, smoking, and risky alcohol intake) and some aspects of individual-level socioeconomic position (education and household income). Those living in mixed land use areas (i.e. with high variability in greenness) may have greater access to both destinations and green/natural space, which may influence positive lifestyle behaviours such as using active transport. The analyses in this study could adjust for physical activity level, therefore confounding could account for some of the observed association.

Neighbourhood **percentage green space** was linked to the addresses of 8,158 adult respondents in the 2006/2007 New Zealand Health Survey (NZHS) (Richardson et al., 2013). Compared to those living in areas with the least green space (<15.7%), CVD risk was significantly lower in neighbourhoods with 33.3-69.8 percent green space (OR 0.80, 95% CI 0.64-0.99). However, the association was not statistically significant when CVD among people living in areas with the least green space was compared to those in areas with 15.7-33.2 percent green space (OR 0.82, 95% CI 0.67-1.00) or the most (>69.8%) green space (OR 0.84, 95% CI 0.65-1.08). Increased levels of physical activity among respondents were independently associated with a lower risk of CVD.

Road traffic volume and noise

Two studies provide some evidence to suggest that living near roads with high traffic noise and volumes, may be associated with CVD morbidity. Firstly, a case-control study of 3,666 adults in Sweden found that exposure to higher long-term levels of **road traffic noise** was associated with a significantly higher risk of myocardial infarction (OR 1.38, 95% CI 1.11-1.71) (Selander et al., 2009). Case control studies can also be prone to confounding (Mann, 2003), and in this study, statistical adjustments were made for smoking, physical inactivity, diabetes, air pollution, and occupational noise exposure (Selander et al., 2009).

Further, the relationship between living in close **proximity to busy roads** and self-reported cardiac disease was investigated among Estonian adults in 2000-2001 (n=1,708) and 2011-2012 (n=1,370) (Pindus et al., 2015). The prevalence of cardiac disease was significantly higher among those who lived within 150 metres of roads with high total traffic (i.e. ≥10,000 vehicles per day; in 2000-2001: OR 1.91, 95% CI 1.15-3.16 and in 2011-2012: OR 1.58, 95% CI 1.01-2.47). There was also a significant association between cardiac disease prevalence and living within 150 metres of roads with greater numbers of heavy duty vehicles per day in 2000-2001 (≥250 vehicles: OR 1.49, 95% CI 1.09-2.04 and 500 vehicles: OR 1.52, 95% CI 1.04-2.24), but not in 2011-2012 (≥250 vehicles: OR 1.00, 95% CI 0.68-1.46 and (≥500 vehicles: OR 1.37, 95% CI 0.87-2.16).

When the data were assessed longitudinally over the 11 years, participants living within 150 metres of roads with high total traffic were twice as likely to develop cardiac disease (OR 2.02, 95% CI 1.07-3.80) than those who lived further away (Pindus et al., 2015). However, there was no significant association between developing cardiac disease and living within 150 metres of roads with greater numbers of heavy duty vehicles per day (≥250 vehicles: OR 1.08, 95% CI 0.59-1.98 and ≥500 vehicles: OR 1.19, 95% CI 0.59-2.39). The number of new cases of cardiac disease at the study endpoint was small (18 new cases living near roads with ≥10,000 vehicles/day, 25 new cases living near roads with ≥250 heavy duty vehicles/day, and 16 new cases living near roads with ≥500 heavy duty vehicles/day), therefore the confidence intervals are wide for these estimates. This study adjusted for age, BMI, smoking history and education in the analyses, but not air pollution (for which proximity to busy roads may also act as a marker for exposure).

Air pollution

A large number of studies have investigated the association between exposure to outdoor air pollution and CVD. Systematic reviews and meta-analyses of time-series and case-crossover studies have found short-term exposure (≤7 days) to air pollutants (i.e. carbon monoxide, sulphur dioxide, nitrogen dioxide, $PM_{2.5}$ and PM_{10}) to be associated with significantly increased risk of heart failure (Shah et al., 2013), stroke (Shah et al., 2015), and myocardial infarction (Luo et al., 2015; Martinelli, Olivieri, & Girelli, 2013; Mustafić et al., 2012). A meta-analysis of 11 cohorts from five European countries indicates that greater long-term exposure to PM_{10} (but not coarse PM, $PM_{2.5}$, nitrogen dioxide, or nitrogen oxides) is associated with a significantly increased risk of coronary events (e.g. myocardial infarction and other acute forms of ischaemic heart disease, HR 1.12, 95% CI 1.01-1.25) (Cesaroni et al., 2014) but not stroke incidence (Stafoggia et al., 2014). It has been estimated that 24 percent of ischaemic heart disease, and 26 percent of stroke, worldwide is attributable to ambient air pollution (Prüss-Ustün et al., 2016).

Food and alcohol retail

A significant association between the number of **fast food restaurants** in the neighbourhood and ischaemic stroke prevalence was observed in a cross-sectional study of 1,247 adults in the USA (Morgenstern et al., 2009). A 13 percent higher risk of ischaemic stroke was observed in neighbourhoods with the highest number of fast food restaurants compared to those with the lowest number (RR 1.13, 95% CI 1.02-1.25) after adjustment for ethnicity, gender, age, and neighbourhood socioeconomic status. The risk of stroke increased by 1 percent for every fast food restaurant in the neighbourhood (RR 1.01, 95% CI 1.00-1.01, p=0.02).

A nationwide longitudinal study of 2,165,000 adults in Sweden examined the relationship between various neighbourhood resources and CHD hospitalisation (for morbidity or mortality) over 2 years (Kawakami, Li, & Sundquist, 2011). No statistically significant associations were found between the incidence of CHD hospitalisation and the **availability of fast food restaurants** or **bars/pubs** in the neighbourhood among men (fast food restaurants: OR 1.00, 95% CI 0.97-1.02 and bars/pubs: OR 0.99, 95% CI 0.95-1.04) or women (fast food restaurants: OR 1.00, 95% CI 0.96-1.04 and bars/pubs: OR 1.02, 95% CI 0.96-1.08). No significant associations were found either when restaurant/bar/pub availability was within a 500 metre, or 1,000 metre, radius of each participant's home (rather than the small area unit "neighbourhood" measure, as described above). The authors suggest that neighbourhood deprivation and individual-level income and education play a greater role in CHD than the food and alcohol retail environment as when these factors were taken into account in the analyses, any significant findings no longer remained.

Physical activity and health care facilities

In the Swedish longitudinal study mentioned above, no statistically significant associations were found between the incidence of CHD hospitalisation and the **availability of physical activity facilities** or **health care facilities** in the neighbourhood among men (physical activity: OR 1.00, 95% CI 0.97-1.03 and health care: OR 1.02, 95% CI 0.99-1.05) or women (physical activity: OR 1.03, 95% CI 0.99-1.08 and health care: OR 1.01, 95% CI 0.97-1.05) (Kawakami et al., 2011). No significant associations were found either when resource availability was within a 500 metre, or 1,000 metre, radius of each participant's home (rather than the "neighbourhood" measure, as used above).

Urban sprawl

Living in a more compact urban area (i.e. the opposite of **urban sprawl**) at baseline was associated with a significantly lower risk of a CHD-related event, or CHD-related death or myocardial infarction over an average of 7.5 years among a cohort of 45,376 females in the USA (CHD-related event: HR 0.95, 95% CI 0.91-0.99 and CHD-related death or myocardial infarction: HR 0.92, 95% CI 0.86-0.98) (Griffin et al., 2013). When four aspects of urban sprawl were considered separately, significant associations were found for **residential density** (CHD-related event: HR 0.94, 95% CI 0.91-0.97 and CHD-related death or myocardial infarction: HR 0.90, 95% CI 0.86-0.95) and **land-use mix** (CHD-related event: HR 0.99, 95% CI 0.94-1.04 and CHD-related death or myocardial infarction: HR 0.90, 95% CI 0.84-0.97), but not **street connectivity** (CHD-related event: HR 0.98, 95% CI 0.94-1.02 and CHD-related death or myocardial infarction: HR 0.95, 95% CI 0.89-1.01) or **centredness** (i.e. the degree to which development is focussed on the region's core; CHD-related event: HR 0.95, 95% CI 0.91-1.00 and CHD-related death or myocardial infarction: HR 0.98, 95% CI 0.91-1.05). Non-Hispanic black participants experienced the largest protective effect of urban compactness.

Further, the incidence of self-reported stroke or "heart problems" was not significantly associated with **street connectivity** or **urban density** (i.e. number of food stores, restaurants, and housing units per square metre, and population density) in a longitudinal study of more than 10,000 older men and women living in the USA (Freedman et al., 2011).

Neighbourhood deprivation and other features

There was no significant association between self-reported CHD and **neighbourhood disadvantage** among residents of 200 Brisbane neighbourhoods, once individual-level socioeconomic position was taken into account (Rachele et al., 2016). The authors highlight the importance of including individual-level socioeconomic factors in analyses of neighbourhood-level deprivation and chronic disease outcomes, as not including these factors "may inflate neighborhood-level effects". This is of particular note because people who live in more disadvantaged neighbourhoods are more likely to have "lower individual-level socioeconomic characteristics". However, as described in the previous section, residents of the most disadvantaged neighbourhoods were three times more likely to report having both CHD and T2DM (concurrently) than those living in the least disadvantaged neighbourhoods (OR 3.00, 95% CI 1.49-6.13).

On the other hand, two longitudinal studies provide some evidence of a relationship between CVD and **neighbourhood deprivation**. Over a 3-year period, older adults in the UK were significantly more likely to be diagnosed with ischaemic heart disease if they lived in the mid-deprived (OR 1.29, 95% CI 1.04-1.62), second-most deprived (OR 1.42, 95% CI 1.11-1.81), or most deprived (OR 1.86, 95% CI 1.42-2.42) neighbourhoods (Jordan et al., 2014). The incidence of self-reported "heart problems" was assessed in a longitudinal study of 10,459 older men and women living in the USA (Freedman et al., 2011). Among women, living in an **economically disadvantaged** area was significantly associated with 20 percent higher odds of developing heart problems (95% CI 1.00-1.43, p<0.05). However, this finding was not significant among men (OR 0.98, 95% CI 0.79-1.22). There were no statistically significant relationships between the onset of heart problems and neighbourhood **economic advantage**, high **immigrant area**, high **crime** and more **segregation**, or **residential stability**. The incidence of stroke was also assessed among 12,777 participants in the same study, and there were no significant associations with any of the neighbourhood factors listed above.

The relationship between **neighbourhood-level stressors** (several combined, including aspects of safety, violence, social cohesion, and aesthetic quality) and incident CHD over an average of 10 years was investigated among 6,105 adults in the USA (Kershaw et al., 2015). Compared to those with the lowest exposure to neighbourhood stressors, participants with moderate exposure had 50 percent higher CHD risk (95% CI 1.07-2.10), after adjustment for individual-level stressors and risk factors for CHD. However, there was no significant association for those with the highest exposure to neighbourhood stressors (HR 1.21, 95% CI 0.79-1.84).

Depression and anxiety

It has been proposed that the urban environment could influence mental health through a variety of mechanisms, including facilitating formal and informal social interactions, exposure to the restorative effects of nature, providing opportunities for physical activity, and exposure to stressors (e.g. crime, disorder, noise, vandalism). The studies presented in this section only include participants with physician-diagnosed depression and/or anxiety disorder. While there are a relatively small number of studies included here, a growing number of recently-published studies have investigated the association between some indicators of mental health (such as survey-based measures of psychological distress, psychological wellbeing, perceived mental health, depressive symptoms) and various urban characteristics (e.g. (Alcock et al., 2014; Alegría, Molina, & Chen, 2014; Annerstedt et al., 2012; Astell-Burt, Feng, & Kolt, 2013; Astell-Burt, Mitchell, & Hartig, 2014c; Casciano & Massey, 2012; Chong et al., 2013; Cohen-Cline, Turkheimer, & Duncan, 2015; Cooper-Vince et al., 2014; Francis et al., 2012; Furr-Holden et al., 2011; Gariépy et al., 2014; Gariépy et al., 2015a; Gariépy et al., 2015b; Jones-Rounds, Evans, & Braubach, 2014; Kamimura et al., 2014; Miles, Coutts, & Mohamadi, 2012; Mitchell, 2013; Mitchell et al., 2015; Power et al., 2015; Roh et al., 2011; Saarloos et al., 2011; Schreckenberg, Griefahn, & Meis, 2010; Shanahan et al., 2016; Sugiyama et al., 2016; Tomita & Burns, 2013; Vallée et al., 2011; van den Berg et al., 2010)).

Green space

Two cross-sectional studies suggest that access to neighbourhood **green space** may be associated with the prevalence of depression and anxiety among adults. The annual prevalence rate of depression in The Netherlands was significantly lower among those living in areas with more green space within a 1 kilometre (OR 0.96, 95% CI 0.95-0.98), but not 3 kilometre (OR 0.98, 95% CI 0.96-1.00) radius of their home (Maas et al., 2009). In addition, the annual prevalence rate of anxiety disorder was significantly lower among those living in areas with more green space within both a 1 kilometre (OR 0.95, 95% CI 0.94-0.97), and 3 kilometre (OR 0.96, 95% CI 0.93-0.99) radius of their home (Maas et al., 2009). In an effort to exclude indirect selection among the study population (i.e. when people with certain characteristics tend to live in a greener environment), several socioeconomic and demographic factors were controlled for in the statistical analyses (i.e. gender, age, highest level of completed education, work status, and healthcare insurance type - an indicator of socioeconomic status).

In addition, a study of Auckland adults found that living closer to a useable green space was associated with significantly lower anxiety/mood disorder treatment counts (IRR 1.35, 95% CI 1.02-1.79, p=0.033) , where treatment counts decreased by 3.5 percent for every 100 metres decrease in distance to useable green space (Nutsford, Pearson, & Kingham, 2013). Similarly, living closer to a greater proportion of total (IRR 0.96, 95% CI 0.94-0.97, p<0.001) and useable (IRR 0.96, 95% CI 0.95-0.98, p<0.001) green space within 3 kilometres of residence. Every 1 percent increase the proportion of total or useable green space within 3 kilometres was associated with a 4 percent lower treatment count. However, the proportion of total (IRR 1.00, 95% CI 1.00-1.01, p=0.449) and useable (IRR 1.00, 95% CI 1.00-1.01, p=0.36) green space within a smaller area (300m of residence), or distance to nearest total green space (IRR 1.3, 95% CI 0.95-1.7, p=0.107) were not significantly associated with anxiety/mood disorder treatment counts.

Alcohol retail

No significant associations were found between the presence of one or more **alcohol outlets** within 1.6 kilometres of home and either self-reported medical diagnosis of anxiety, stress or depression (OR 1.07, 95% CI 0.92-1.24, p=0.400) or hospital contact for anxiety, stress or depression (OR 1.56, 95% CI 0.98-2.49, p=0.059) in a cross-sectional study in Western Australia (Pereira et al., 2013).

Neighbourhood deprivation

A systematic review of 14 longitudinal studies found mixed evidence of a relationship between **neighbourhood socioeconomic conditions** and depression (or depressive symptoms) among adults and adolescents living in high-income countries (Richardson et al., 2015). When the findings of six relatively homogenous studies which had a follow-up duration of 5 years or longer were pooled in a meta-analysis, no significant association was found (OR 1.00, 95% CI 0.95-1.06). As the studies included in the review were trying to ascertain whether the neighbourhood socioeconomic environment had an effect on depression that was independent of individual-level characteristics, all studies controlled for at least some individual-level socioeconomic factors. However, it is possible that some residual confounding may have remained. In addition, the authors suggest that exploring specific aspects of the neighbourhood environment that interact with socioeconomic conditions (such as crime and access to health-promoting resources) may provide more consistent results.

Chronic obstructive pulmonary disease

Air pollution

Reviews suggest that there is a tendency towards higher COPD prevalence and incidence with greater exposure to outdoor air pollution, however findings are inconsistent and often not statistically significant (Hansel, McCormack, & Kim, 2016; Schikowski et al., 2014a; Schikowski et al., 2014b; Song et al., 2014). Individual studies included in the reviews were heterogeneous in terms of their design, characterisation of exposure to air pollutants, and measurement of COPD outcomes. It has been estimated that 9 percent of COPD worldwide is attributable to ambient air pollution (Prüss-Ustün et al., 2016).

Neighbourhood deprivation

In a study of older adults from North Staffordshire followed up over 3 years, participants were significantly more likely to be diagnosed with COPD if they lived in the mid-deprived (OR 1.37, 95% CI 1.00-1.87), second-most deprived (OR 1.90, 95% CI 1.37-2.65), or most deprived (OR 2.37, 95% CI 1.67-3.35) neighbourhoods compared to those living in the least deprived neighbourhoods (Jordan et al., 2014). Those living in the second least-deprived neighbourhoods were not at a significantly increased risk of COPD compared to those living in the least deprived neighbourhoods (OR 1.08, 95% CI 0.78-1.50). This relationship between COPD and neighbourhood deprivation may reflect a greater prevalence of unhealthy lifestyle behaviours (such as smoking and physical inactivity) among people living in more deprived areas. These individual-level lifestyle factors were not accounted for in the statistical analyses.

Cancers

Few studies have robustly assessed the relationship between urban characteristics and cancer prevalence or incidence whilst controlling for possible confounding variables (Gomez et al., 2015).

Green space

In a cross-sectional study from The Netherlands the annual prevalence rate of cancer (type not specified) was not significantly associated with **green space** within a 1 kilometre (OR 1.00, 95% CI 0.98-1.02), or 3 kilometre (OR 0.99, 95% CI 0.95-1.03) radius of home (Maas et al., 2009). Further, a study of 267,072 Australians found that people living in areas with more **green space** had significantly higher odds of skin cancer, after controlling for multiple individual-level variables, including time spent outdoors (Astell-Burt, Feng, & Kolt, 2014b). This study highlights that not all evidence suggests that the potential relationships between green space and health are positive, and in the case of cancer it is important to consider effects by type as they have differing aetiology.

Air pollution

In two separate systematic reviews and meta-analyses of cohort and case-control studies, exposure to higher levels of $PM_{2.5}$ (RR 1.09, 95% CI 1.04-1.14), PM_{10} (RR 1.08, 95% CI 1.00-1.17), nitrogen oxides (RR 1.03, 95% CI 1.01-1.05), and nitrogen dioxide (RR 1.04, 95% CI 1.01-1.09) was found to be significantly associated with an increased risk of lung cancer (Hamra et al., 2014; Hamra et al., 2015).

It has been estimated that 14 percent of lung cancer worldwide is attributable to ambient air pollution (Prüss-Ustün et al., 2016).

Night-time outdoor light exposure

Exposure to light during the night can disrupt the body's circadian system, and it has been proposed that circadian disruption may increase the risk of some cancers. Two recently-published studies from the USA have investigated the relationship between breast cancer and area-level exposure to **outdoor light at night** using satellite imagery data, with inconsistent results. In Georgia, high exposure to light at night was associated with 12 percent higher odds of breast cancer (95% CI 1.04-1.20), compared to the lowest exposure (Bauer et al., 2013). On the other hand, no statistically significant association was found between exposure to outdoor light at night and invasive breast cancer (p=0.06) among a prospective cross-sectional cohort of 106,731 female teachers in California (Hurley et al., 2014). These two studies used different methods, and in the former, light exposure was estimated using the average exposure for 9-16 years prior to cancer diagnosis, while in the latter study an average from 1 year was used. Using data from a longer time period may give a more accurate estimate of long-term exposure to outdoor light at night.

Other neighbourhood features

The incidence of self-reported cancer or malignant tumour (excluding minor skin cancers) over 2 years was assessed among 12,000 older men and women living in the USA in relation to several neighbourhood features (Freedman et al., 2011). Living in an area with **high crime and more segregation** was associated with significantly higher odds of developing cancer or malignant tumour (men: OR 1.31, 95% CI 1.10-1.56, p<0.01 and women: OR 1.25, 95% CI 1.04-1.52, p<0.05). There were no statistically significant relationships between the onset of cancer or malignant tumour and neighbourhood **economic advantage or disadvantage**, high **immigrant** area, **residential stability**, **street connectivity**, or **density**. The authors suggest that a biological stress response may be a mechanism by which neighbourhood crime and segregation may influence cancer development.

Arthritis

The studies included in this section examine some different types of arthritis (osteoarthritis and rheumatoid arthritis) separately, or arthritis as a whole, where the type has not been specified. Being overweight or obese is a modifiable risk factor for osteoarthritis (Centers for Disease Control and Prevention, 2016), however BMI/weight status has not been included as a potential confounding factor in the statistical analyses in any of the studies described below.

Green space

The annual prevalence rate of arthritis and osteoarthritis in The Netherlands was not significantly associated with **green space** within a 1 kilometre (arthritis: OR 0.99, 95% CI 0.97-1.01 and osteoarthritis: OR 0.97, 95% CI 0.93-1.01), or 3 kilometre (arthritis: OR 1.00, 95% CI 0.96-1.04 and osteoarthritis: OR 0.97, 95% CI 0.92-1.03) radius of home (Maas et al., 2009).

Neighbourhood deprivation and other features

The findings on neighbourhood deprivation and arthritis are mixed. Among a cross-sectional sample of 10,757 Australian adults, residents of the most **disadvantaged neighbourhoods** were significantly more likely than those in the least disadvantaged neighbourhoods to report having arthritis (OR 1.4, 95% CI 1.2-1.7) (Brennan & Turrell, 2012). On the other hand, among 18,047 UK adults, there was no significant association between neighbourhood deprivation and likelihood of diagnosis for osteoarthritis and/or joint pain over a 3-year period (Jordan et al., 2014).

The incidence of self-reported arthritis or rheumatism over 2 years was assessed among 5,511 older men and women living in the USA (Freedman et al., 2011). There were no statistically significant relationships between the onset of arthritis or rheumatism and any of the following neighbourhood features: **economic advantage or disadvantage**, high **immigrant** area, high **crime** and more **segregation**, **residential stability**, **street connectivity**, **air pollution**, or **density**.

Summary

In summary, literature sourced for this review provides some evidence of associations between several physical and social neighbourhood-level urban characteristics and selected NCDs (**Figure**). The characteristics listed below have been found to be significantly associated with some, but not all, NCDs considered in this evidence review.

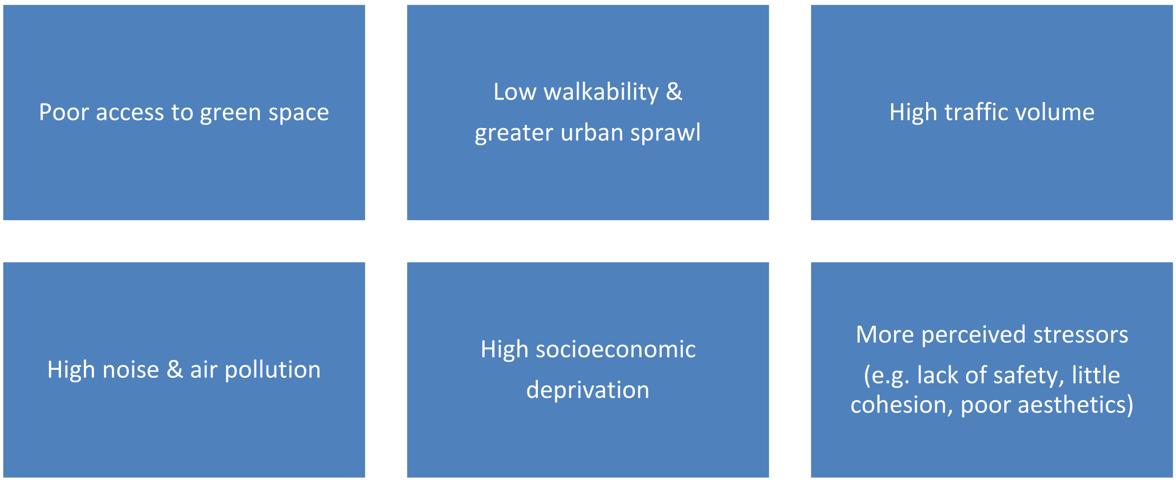

Figure 5. Urban characteristics most consistently associated with selected NCDs (T2DM, CVD, depression and anxiety, COPD, cancers, and arthritis).

The impacts of urban interventions on non-communicable disease risk factors and morbidity

Neighbourhood- and city-wide interventions

Several recent reviews collate studies of different types of neighbourhood- and city-wide interventions that have been implemented to increase physical activity, and have found modest positive impacts. Reviews of interventions to increase cycling found evidence of small increases with the provision, extension or upgrading of **cycling infrastructure**, such as cycling lanes, road/path markings, and parking (Pucher, Dill, & Handy, 2010; Scheepers et al., 2014; Yang et al., 2010). Greatest effects were observed when multicomponent interventions (such as safety measures, supportive land-use planning and restrictions on car use) were introduced to complement cycling infrastructure changes (Pucher et al., 2010). Many individual case studies of urban interventions to increase physical activity have been described (Fisher & Griffin, 2016; National Heart Foundation of Australia, 2009; Public Health Advisory Committee, 2010; Pucher et al., 2010; Shaw et al., 2016).

There is some discussion that increasing active transport may not necessarily increase overall physical activity, as recreational activity may decrease as compensation. This was found to be the case in a cross-sectional study from New Zealand, where the travel habits of residents from two North Island cities (New Plymouth and Hastings) which implemented a programme of **infrastructure investment** (such as on-road painted cycle lanes, shared paths, and improved surface quality and pathway connectivity) and active travel promotion in 2011 was compared to two control cities (Whanganui and Masterton) (Keall et al., 2015). After 2 years, there was a significant 37 percent increase in the odds of taking a trip using active transport in intervention cities. However, there was no significant change in physical activity levels overall (Keall et al., 2015).

However, this was not the case in the UK-based iConnect longitudinal study of more than 1,000 adults, which investigated the impacts of newly-constructed **cycling and walking infrastructure** on travel modes (Ogilvie et al., 2012; Ogilvie et al., 2011; Sustrans, 2016). It found that the new routes were used predominantly for recreation (Goodman et al., 2013, 2014; Sahlqvist et al., 2015; Sustrans, 2016), and over 2 years, those who lived closest to the new infrastructure, and those who increased their use of active travel, engaged in significantly more physical activity (Goodman et al., 2014; Sahlqvist et al., 2013). Greater use of active transport among those living closest to new infrastructure was also reported in a sub-analysis of the of the New Zealand study mentioned above (Howden-Chapman et al., 2015). Increases in walking and cycling for transport were not outweighed by reductions in recreational forms of physical activity (Goodman et al., 2014; Sahlqvist et al., 2013). The increases in physical activity were greatest among those with no car in their household (Goodman et al., 2014), and the routes were used primarily by existing walkers and cyclists, and those who were more socioeconomically advantaged (Goodman et al., 2013). The authors proposed that larger improvements on poor infrastructure are more likely to be more effective at increasing physical activity than small improvements on “already satisfactory” infrastructure (Goodman et al., 2014; Sahlqvist et al., 2015; Sustrans, 2016).

A review of **urban green space interventions** (such as renovations to amenities, fencing, landscaping, and paths) found some evidence of increased physical activity, and more promising evidence for greater physical activity when changes were accompanied by a physical activity programme (Hunter et al., 2015). Further, a systematic review of **built environment changes** from naturally-occurring experiments found few studies that directly assessed physical activity or BMI using objective measures (Mayne, Auchincloss, & Michael, 2015). However, a small number of studies found modest improvements in physical activity-related measures after improvements were made to green space and outdoor play/exercise equipment, and active transport infrastructure. One longitudinal study included in this review found that the introduction of a new light-rail system in one USA city was associated with a significant 18 percent reduction in self-reported BMI, and 81 percent lower odds of becoming obese over time (MacDonald et al., 2010).

Residential relocation

Two longitudinal studies have found that **moving to a more walkable neighbourhood** has some positive effects on BMI. Over 12 years, moving from a low- to high-walkable neighbourhood was associated with a significant decrease in BMI (change in BMI with increase in walkability of two quartiles: -1.09kg/m^2, 95% CI -1.77 to -0.41) among 1,417 Canadian males (Wasfi et al., 2016). The association was not significant among females in the study (estimates not reported). A significant decrease in BMI with moving to a more walkable area was also found among 701 USA adults over an average of 6 years (mean change in BMI for every 10-point increase in walkability score: -0.06kg/m^2, 95% CI -0.12 to -0.01, p=0.02) (Hirsch et al., 2014).

A quasi-experimental study from the USA suggests that **moving from a high-poverty to a low-poverty neighbourhood** may be associated with better health outcomes among women (Ludwig et al., 2011). Between 1994 and 1998, women with children living in selected public housing developments in high-poverty areas were invited to participate in a “lottery” to receive a rent-subsidy voucher. Participants (n=4,498) were randomly assigned to receive a rent-subsidy voucher to use in a low-poverty area, a standard voucher to use in any area, or no voucher (a control group). Among the 1,788 women assigned to receive a rent-subsidy voucher to use in a low-poverty area, 48 percent used the voucher to move residence. Follow-up 10-15 years later (in 2008-2010) found that compared to those in the control group, women assigned a rent-subsidy voucher to live in a lower-poverty area had a lower risk of high-risk obesity (BMI ≥35: -4.61 percentage points, 95% CI -8.54 to -0.69, p=0.02 and BMI ≥40: -3.38 percentage points, 95% CI -6.39 to -0.36, p=0.03) and T2DM (i.e. HbA1c ≥6.5%, -4.31 percentage points, 95% CI -7.82 to -0.80, p=0.02). There were no statistically significant differences in obesity or T2DM prevalence between the control group and those who received the standard rent-subsidy vouchers.

Housing development guidelines

In the quasi-experimental longitudinal RESIDE study in Perth, Western Australia, baseline data was collected from 1,813 adults prior to them moving into their newly-built home in one of 75 new housing developments (Giles-Corti et al., 2008), and follow-up was conducted approximately 1, 3, 4 and 7 years after relocation. Nineteen “liveable” housing developments used the State Government Liveable Neighbourhoods Community Design Guidelines (LNCDG, including aspects of community design, movement network, lot layout, and public parkland) which aimed to reduce suburban sprawl and car dependence, and encourage active transport (Giles-Corti et al., 2008).

The “liveable” developments had significantly greater objectively-measured street connectivity, residential density, land-use mix, access to services, and more public open spaces and public transport stops than “conventional” developments, when assessed 1 and 3 years after relocation (Christian et al., 2013). At these time points, residents of liveable developments (n=299) were significantly more likely to perceive greater access to mixed-use services, infrastructure for safety and walking, footpaths on both sides of the road, more destinations, and enhanced aesthetics, than residents of conventional developments (n=528). However, there was no significant difference in the amount of time per week spent walking (in total), walking for transport, or walking for recreation between residents of liveable and conventional developments (Christian et al., 2013).

When the 19 liveable developments were compared with 17 matched conventional developments 5-6 years after approval of the developments, there was no significant difference in their compliance with implementing the 60 requirements in the LNCDG, and the average compliance was less than 50 percent (Hooper, Giles-Corti, & Knuiman, 2014). This indicates that the implementation of the LNCDG for the liveable developments was incomplete, and there were few significant differences in measured outcomes (e.g. street connectivity) between the two development types. However, increasing compliance with the guidelines was associated with increased odds of walking for transport (Hooper et al., 2014) and decreased odds of self-reported victimisation (Foster et al., 2015), but not consistently associated with police-reported crime (Foster et al., 2015), walking for recreation, or walking for an hour or more for transport or recreation (Hooper et al., 2014).

With the aim to provide evidence to support urban design planning and policy-making, specific design features from the LNCDG were identified that showed the strongest associations with walking behaviours (Hooper et al., 2015a; Hooper et al., 2015b). The four “building blocks” were:

1. *Structure and connectedness*, which included the “macro” design features that enable movement – connectivity of street networks, proximity to destinations, street block density (a larger number of smaller blocks, and more compact and denser developments), and external access points.
2. *Activities and mix*, which included access to destinations – mix of land uses and activities, diversity of destinations, neighbourhood centres with “street-front”-type retail elements, and public open spaces.
3. *Design details and qualities*, which included the “micro” design features that enhance the walking experience – quality design, inclusion of footpaths, landscaping, trees for shade, building frontage, and street design.
4. *Residential density*, which supports the three other building blocks, to decrease the distance between home and destinations (Hooper et al., 2015b).

Summary

Examples included in this section indicate that interventions to improve the urban environment (particularly active transport infrastructure and green space) may contribute to greater physical activity, and healthier weight, among local residents.

Research specific to Aotearoa New Zealand

Most of the evidence included in this review is from the USA, Canada, Europe, Australia and the UK. Generalising the findings to a New Zealand setting is challenging due to potential differences in the physical and social environments of urban centres in these high-income countries. Therefore, research conducted in New Zealand is summarised in more detail here to provide evidence relevant to the local environment.

Neighbourhood deprivation and urban characteristics

International and local evidence suggests that greater neighbourhood socioeconomic deprivation is associated with significantly poorer health outcomes among residents (e.g. (Chan et al., 2008; Diez Roux et al., 2010; Haynes, Pearce, & Barnett, 2008; Joshy et al., 2009; McFadden et al., 2004; McKenzie, Ellison-Loschmann, & Jeffreys, 2010; Riddell, 2005; Sommer et al., 2015). It has been suggested that factors such as the distribution of neighbourhood resources and exposure to stressors (such as traffic noise and air pollution) may contribute to these inequities. In light of this, several New Zealand studies have considered how the urban characteristics of more socioeconomically disadvantaged areas may differ from more advantaged areas[1].

As part of the URBAN study, 69 **public open spaces** within 12 Auckland neighbourhoods were scored according to their attributes (i.e. amenities available, safety, activities, and environment quality) (Badland et al., 2010). Public open spaces in more deprived neighbourhoods had significantly more activities ($p \leq 0.05$) and safety features ($p \leq 0.001$), however poorer environmental quality ($p \leq 0.001$), than spaces in less deprived neighbourhoods. There was no significant difference between more and less deprived neighbourhoods in terms of the amenities available in these public open spaces ($p=0.06$). It was also found in a study of 1,009 urban areas across New Zealand that while the amount of **total green space** was lower in areas of higher deprivation, these areas had relatively higher amounts of **useable green space** (Richardson et al., 2010). It may be that total green space in more affluent areas is greater, but is not available for use by the public, such as the parks and sports grounds found in less affluent areas.

In a study of North Shore City and Waitakere City it was found that access to **community resources** (i.e. recreation, public transport, communication, retail, education, health, social and cultural facilities) was significantly better in more deprived areas ($p<0.0001$) (Field et al., 2004). This finding was corroborated in a nationwide study, where those living in more deprived neighbourhoods had significantly shorter travel times (by car) to marae and community health, diet, recreation, and education resources (all $p<0.0001$), but not beaches ($p=0.291$), compared to those living in less deprived neighbourhoods (Pearce et al., 2007b). Further analyses indicated that this was the case for

---

[1] New Zealand studies most often use the New Zealand Index of Deprivation (NZDep) to describe the general socioeconomic deprivation of an area. It is a small-area-based relative deprivation index based on nine socioeconomic variables from the New Zealand Census. NZDep scores are usually categorised into tenths (deciles), numbered from 1 (least deprived) to 10 (most deprived) (Atkinson, Salmond, & Crampton, 2014; Salmond, Crampton, & Atkinson, 2007).

urban and intermediate urban/rural areas, but not rural areas, and in Canterbury access to all of the resources studied was better in the most deprived compared to the least deprived neighbourhoods (Pearce et al., 2008b). The community resource indices used in these two studies did not take into account factors such as the quality or accessibility (for example, in terms of cost) of these resources, only geographical proximity. A further point not covered in these studies is the potential for some services and resources to be clustered in "flatter" (less hilly) areas, which may also be more likely to be areas categorised as more deprived.

Data on the location of **food outlets** across New Zealand were investigated, and it was found that travel time to fast food restaurants (multinational and local) was significantly shorter in areas of higher deprivation (all $p<0.001$) (Pearce et al., 2007a). Similarly, travel time to food outlets potentially selling healthier food options (e.g. supermarkets) was significantly shorter in areas of higher deprivation ($p<0.001$). Distances between schools and food outlets were also shorter for schools in more deprived areas (all $p<0.001$) (Pearce et al., 2007a). Similarly, multiple studies have indicated that the density of convenience, fast food, and takeaway outlets is greater around schools in more deprived areas (Day & Pearce, 2011; Day, Pearce, & Pearson, 2015; Vandevijvere et al., 2016). In the largest and most recent national study it was found that the density of convenience stores (but not fast food and takeaway outlets) was significantly greater around urban schools in the most deprived areas compared to those in the least deprived areas (median 1.2 stores/km compared to 0.9 stores/km, $p<0.01$) (Vandevijvere et al., 2016).

Likewise, several studies have found that **alcohol retail outlets** (Ayuka, Barnett, & Pearce, 2014; Ayuka Owuor, 2010; Connor et al., 2011; Hay et al., 2009; Pearce, Day, & Witten, 2008a) and **tobacco retail outlets** (Bowie et al., 2013; Marsh, Doscher, & Robertson, 2013; Pearce et al., 2009b) are disproportionately located in areas of higher socioeconomic deprivation.

Associations between urban characteristics and risk factors for non-communicable diseases

Findings from studies conducted in New Zealand investigating associations between urban characteristics and the NCD risk factors considered in this review are presented here.

Physical inactivity

Access to parks (measured in minutes, by car) was not significantly associated with physical activity or sedentary behaviour among 12,529 adult respondents in the 2002/2003 NZHS (Witten et al., 2008). When **access to beaches** was considered, findings were inconsistent. Neighbourhood **green space** was linked to the addresses of 8,158 adult respondents in the 2006/2007 NZHS (Richardson et al., 2013). Those living in the greenest areas were 44 percent more likely meet physical activity recommendations (i.e. at least 150 minutes/week) compared to those living in the least green areas (95% CI 1.19-1.74).

Awareness of **local physical activity resources** (such as cycle lanes or paths, walking tracks, gyms, and playing fields) was associated with higher self-reported physical activity in a nationally-representative postal survey of 8,038 adults (Garrett, Schluter, & Schofield, 2012). As this is a cross-sectional survey, it is not possible to determine the direction of causality, and it could be that those who are physically active in their community may be more likely to notice the nearby resources available to them. As mentioned in a previous section, there was a significant increase in the odds of using active transport in New Plymouth and Hastings after **infrastructure investment,** compared to two control cities (Whanganui and Masterton) (OR 1.37, 95% CI 1.08-1.73), however there was no significant change in physical activity levels overall (Keall et al., 2015).

Two large-scale cross-sectional studies, Kids in the City and URBAN, have investigated associations between the urban environment and physical activity.

Kids in the City

Kids in the City is a cross-sectional study investigating how the urban environment influences the independent mobility and physical activity of children living in diverse urban Auckland neighbourhoods (Oliver et al., 2011). Among 236 children aged 9-13 years, the proportion of out-of-school time spent in moderate-to-vigorous intensity physical activity was significantly higher with fewer **high-speed roads** (p=0.036), and a more **pedestrian/cycling-friendly environment** (p=0.034) near school on weekdays, but not weekends (p=0.152 and p=0.459, respectively) (Oliver et al., 2015a). There was no significant relationship between out-of-school time spent in moderate-to-vigorous physical activity on weekdays or weekends and **street connectivity** (p=0.731 and p=0.253, respectively), **distance to school** (p=0.685 and p=0.193), or **residential density** (p=0.901 and p=0.208). Having more **neighbourhood destinations** was significantly associated with less moderate-to-vigorous physical activity on weekends (p=0.040), but not on weekdays (p=0.443). As mentioned earlier, a meta-analysis also found that more local destinations in a neighbourhood was associated with lower physical activity levels among children, perhaps due to parental concern about safety limiting children’s independent activities in these busier areas (McGrath et al., 2015).

In addition, the proportion of trips made using active modes was significantly higher with greater street connectivity and shorter distance to school on both weekdays (p<0.0001 and p=0.002, respectively) and weekend days (p<0.0001 and p=0.042, respectively) (Oliver et al., 2015a). Having more neighbourhood destination opportunities was significantly associated with greater active transport on weekdays (p=0.050), but not on weekends (p=0.576). There was no significant relationship between using active transport on weekdays or weekends and the ratio of high-speed roads (p=0.067 and p=0.446, respectively), the pedestrian/cycling environment (p=0.485 and p=0.174), or residential density (p=0.553 and p=0.052). Children’s active transport and independently mobile trips were associated with significantly higher objectively-assessed moderate-to-vigorous physical activity during out-of-school hours (Oliver et al., 2016), perhaps indicating that active commuting did not displace other forms of physical activity, but was undertaken in addition to usual daily activities. It is likely that more findings will be published from the Kids in the City study in the near future.

Understanding the Relationship between Activity and Neighbourhoods (URBAN)

Several articles have been published from the URBAN study which investigated different aspects of the built environment and physical activity. The cross-sectional, stratified study collected data from 12 neighbourhoods each in Christchurch, Wellington, Waitakere and North Shore between April 2008 and September 2010 (Badland et al., 2009). Neighbourhoods were selected based on equal representation of walkability (high/low, based on street connectivity, dwelling density, land-use mix, and retail floor area ratio) and population density of Māori residents (high/low). Within each selected neighbourhood, 42 households were randomly selected and an adult (20-65 years) and child (3-12 years, where possible) recruited to participate. Data collected included objective (accelerometer) and self-reported physical activity, neighbourhood perceptions, demographics, interviewer-measured BMI and waist circumference, streetscape audit, and walkability profile.

The associations between physical activity and five objectively-measured aspects of the built environment (**street connectivity, dwelling density, land-use mix, neighbourhood destination accessibility** and **streetscape quality**) were investigated among the 2,033 participating adults (Witten et al., 2012). Among those who self-reported some physical activity, greater accelerometer-measured physical activity was associated with greater street connectivity (weekday and weekend both: OR 1.07, 95% CI 1.02-1.11), destination access (weekday: OR 1.07, 95% CI 1.03-1.11 and weekend: OR 1.05, 95% CI 1.00-1.10) and dwelling density (weekday: OR 1.07, 95% CI 1.03-1.12 and weekend: OR 1.06, 95% CI 1.02-1.12). However, no significant associations were observed for streetscape quality (weekday: OR 1.03, 95% CI 0.99-1.07 and weekend: OR 1.01, 95% CI 0.97-1.06) or land-use mix (weekday: OR 1.03, 95% CI 0.99-1.08 and weekend: OR 1.04, 95% CI 0.99-1.09). For every 1 standard deviation change in built environment characteristics, estimates suggest a mean population-level increase in walking of 57 minutes per week for destination accessibility, 26 minutes per week for street connectivity, and 35 minutes per week for dwelling density.

A recently-published study has investigated whether people who are more "exposed" to, and potentially more reliant on, their neighbourhood (i.e. those not in full-time paid work, women, those with restricted car access, and those with lower income) would have stronger associations between the built environment and physical activity than those less exposed to their neighbourhood (i.e. in full-time paid work, men, full car access, higher income) (Ivory et al., 2015a). The association between **street connectivity** and physical activity was stronger for those with restricted car access on weekdays and weekends, and those on low income on weekdays (but not weekends). The association between **streetscape quality** and physical activity was stronger for females, those not working full-time, and those on low income, on weekdays (but not weekends).

Fourteen focus groups with adult participants residents in four suburbs of Wellington and Auckland collected qualitative information on the social context of being active (Ivory et al., 2015b). Among participants, public open spaces were widely recognised as being important sites for physical activity and social interaction, and people were active in both local and non-local places, depending on the local availability of different destinations. Places for physical activity were deliberately sought out for their aesthetic quality, if possible, and there was a particular focus on the restorative value of being active in pleasant spaces. Street quality and safety were common considerations. Those not engaged in fulltime employment, and women, appeared to have a more intimate knowledge of their local area.

Among 226 children participating in URBAN, there were inconsistent associations between neighbourhood features and accelerometer-assessed out-of-school moderate-to-vigorous physical activity. During times when children usually travel to/from school, children living 1–2 kilometres from school were more active than those living closer or further away (McGrath et al., 2016). After school, children living closest to school were the most active. During weekends and school holidays, neighbourhoods with more **green spaces**, **attractive streets**, or **low-walkability** streets were positively associated with children's activity. On the other hand, neighbourhoods with additional **pedestrian infrastructure** and more **food outlets** were associated with less activity. The authors suggest that additional pedestrian infrastructure, more food outlets and more walkable streets may be indicative of busier urban areas, and parents may have greater concerns about children's safety in these areas, leading to less independent physical activity.

Findings from URBAN were included in a large international study (in collaboration with the International Physical Activity Environment Network, IPEN) combining data from 6,822 adults from 14 cities worldwide (Sallis et al., 2016). This study found a significant association between more physical activity and greater nearby **residential density, public transport density**, and **number of parks**. The difference in physical activity between participants living in the most and least activity-friendly neighbourhoods ranged from 68-89 minutes per week. There was no significant association between physical activity and **land-use mix**, **intersection density**, and **distance to public transport points**. Of the 14 cities included in the analysis, the highest average unadjusted moderate-to-vigorous physical activity (50 minutes/day) was reported in Wellington (Sallis et al., 2016).

Overweight and obesity

In accordance with international findings (see earlier section on overweight and obesity), there is little evidence from four local studies to suggest that access to unhealthy food outlets or green space is associated with overweight and obesity. Distance between home and the nearest *locally-operated* **fast food outlet** was not significantly associated with being overweight (OR 1.04, 95% CI 0.92-1.16) in a national study using data from 12,529 adults participating in the 2002/2003 NZHS (Pearce et al., 2009a). On the other hand, living further away (≥2.8km) from a *multinational* fast food outlet was associated with a 17 percent higher risk of being overweight (95% CI 1.03-1.32). Among 70 children aged 5-14 years from Hamilton, there was no statistically significant association between nearby **number of unhealthy food outlets** (including bakeries, dairies and takeaways) or amount of **green space** (i.e. within 200m of home and school, and within 30m of the estimated route between the two) and BMI (collected in the 2013/2014 NZHS) (Wilson, 2015).

No significant association between access to **green space** or **parks** (measured in minutes, by car) and overweight/obese status was noted among adult respondents in the 2006/2007 and 2002/2003 NZHSs, respectively (Richardson et al., 2013; Witten et al., 2008). However, when **access to beaches** was considered among the 12,529 adults in the 2002/2003 survey, those living closest to the beach had significantly lower BMI than those living further away, after controlling for individual-level socioeconomic variables (Witten et al., 2008). While a potential confounder could be the clustering of more affluent areas near beaches, evidence indicates that there is no significant difference in travel time to beaches for those living in the most deprived compared to the least deprived areas of New Zealand (Pearce et al., 2007b, 2008b).

Among approximately 1,800 adults in the URBAN study (described previously), greater **street connectivity, streetscape quality,** and **neighbourhood destination access** (but not **land-use mix** or **dwelling density**) were associated with a significantly lower BMI (Oliver et al., 2015b). Greater dwelling density, street connectivity, and neighbourhood destination access (but not land-use mix or streetscape quality) were associated with a significantly lower waist circumference. There was a significant mediating effect of physical activity on the relationship between body size and street connectivity, destinations, and dwelling density. No mediating effect of sedentary behaviour between the built environment and body size measures was observed.

Alcohol use

Three studies have considered **alcohol outlet density** and **proximity** and found no significant association with hazardous drinking among adults or adolescents, however there is some evidence for an association with the quantity consumed by adolescents on a typical drinking occasion. In a nationwide study of adults using data from the 2006/2007 NZHS there was no significant association between hazardous or frequent alcohol consumption and distance to, or density of, alcohol outlets (Ayuka et al., 2014). However, groups most influenced by alcohol outlet access and/or density were younger Māori and Pacific males, younger European females, middle-aged European males, and older males. In another national study of adults, there was no significant association between alcohol outlet density and either average annual alcohol consumption or risky drinking, although, off-licence density was significantly associated with binge drinking (Connor et al., 2011). In Auckland, a 2005 study of 1,179 adolescents (12-17 years of age), found the quantity of alcohol consumed on a typical drinking occasion was significantly associated with alcohol outlet density and **neighbourhood deprivation** (both $p<0.05$) (Huckle et al., 2008). These factors were not associated with annual frequency of alcohol consumption. This could indicate that while alcohol outlet density and neighbourhood deprivation may not be related to the number of drinking occasions, people who live in a more deprived area with higher alcohol outlet density may drink more on these occasions.

Associations between **perceived neighbourhood cohesiveness** and alcohol use were investigated using data from 14,757 adults who participated in the 2003 or 2004 national Health Behaviours Survey (Lin et al., 2012). Those who perceived their neighbourhood to be more cohesive had higher annual frequency of alcohol consumption (OR 1.17, 95% CI 1.11-1.23, $p<0.0001$), and lower alcohol consumption on a typical drinking occasion (OR 0.96, 95% CI 0.94-0.99, $p<0.05$). However, when perceived neighbourhood cohesion was considered at the census area unit level (rather than the individual level, as above), these associations were not statistically significant (frequency: OR 0.98, 95% CI 0.85-1.12 and amount: OR 0.95, 95% CI 0.88-1.03). The authors suggest that an individual's own perception of neighbourhood cohesiveness, rather than "the collective perspective of residents" in a neighbourhood, may influence an individual's alcohol use.

Tobacco use

In a study described previously using data from 9,493 adults who participated in the 2003 national Health Behaviours Survey, higher **perceived neighbourhood cohesion** at the individual level was associated with a significantly lower probability of tobacco use (OR 0.91, 95% CI 0.84-0.99, $p<0.05$) and frequency of use (OR 0.88, 95% CI 0.84-0.92, $p<0.0001$) (Lin et al., 2012). However, when perceived neighbourhood cohesion was considered at the census area unit level, there was a significant association between higher neighbourhood cohesion and higher tobacco use frequency (OR 1.18, 95% CI 1.02-1.36, $p<0.05$), but no association with overall tobacco use (OR 1.07, 95% CI

0.84-1.36). This counterintuitive finding that greater cohesion is association with more frequent tobacco use was noted by the authors who suggested that the norms of the community need to also be considered when studying cohesion to determine how the social environment shapes behaviour. For example, a cohesive community with “permissive smoking norms” may be associated with higher levels of smoking just as a cohesive community with strong smoke-free norms may be associated with lower levels of smoking.

Among Year 10 students (≈14-15 years old) across New Zealand, medium and high **tobacco retail outlet density** within 500 metres or 1,000 metres of their school was associated with significantly higher risk of current (but not experimental) smoking (Marsh et al., 2015). Among adults, a national study found no significant association between being a smoker and **travel time** (by car) to the nearest tobacco retail outlet (supermarkets and convenience stores) (Pearce et al., 2009b). Similarly, there was no significant association between being a heavy smoker (as opposed to a light smoker) and travel time to a tobacco retail outlet.

Associations between urban characteristics and non-communicable diseases

Findings from studies conducted in New Zealand investigating associations between urban characteristics and NCD-related morbidity considered in this review are presented here.

Cardiovascular disease

The impact of **residential mobility** on CVD hospitalisations was investigated among a cohort of 641,532 Aucklanders aged 30 years and over (Exeter et al., 2015). Those who moved residence between 2006 and 2012 were 22 percent more likely to have a CVD hospitalisation than those who did not move (95% CI 1.19-1.26). The risk of CVD hospitalisation was highest among those who moved from less to more deprived areas, and those who moved within the most deprived areas.

As reported in a previous section, compared to adults living in areas with the lowest percentage of **green space**, CVD risk was significantly lower in neighbourhoods with moderate (but not the highest) percentage green space (Richardson et al., 2013). Richardson and colleagues (2010) have suggested some possible explanations of why findings on green space and health relationships might differ between New Zealand and other countries. Firstly, there may be a lack of variation in green space exposure in New Zealand compared with other countries, as urban areas in New Zealand may have a relatively high amount of green space present. Secondly, as private gardens tend to be larger in New Zealand, public green spaces may be less important for health. Thirdly, aquatic areas (“blue space”) may also have importance for health in New Zealand as almost two thirds of the population live within 5 kilometres of the sea (Statistics New Zealand, 2008). This may suggest that a measure combining green and blue space may be more closely associated with health in New Zealand than green space alone (Richardson et al., 2010).

Depression and anxiety

As discussed in a previous section, a cross-sectional study of Auckland adults found that living closer to useable **green space**, and a greater proportion of total and useable green space within 3 kilometres were associated with significantly lower anxiety/mood disorder treatment counts

(Nutsford et al., 2013). However, proportion of total and useable green space within 300 metres of residence, or distance to nearest total green space, were not.

Summary

While there does seem to be more “unhealthy” exposures (such as alcohol, tobacco and fast food outlets) in more disadvantaged areas, these areas also have more health-promoting community resources (such as public open/green and recreational spaces, marae, health facilities, education providers and supermarkets). However, the quality and accessibility of the environment and resources in these areas, a factor not often considered in research studies, is an important consideration when looking at the influence of the local environment on health-related behaviours and outcomes. Studies exploring the relationship between New Zealand urban characteristics and physical activity, weight, alcohol and tobacco use, CVD, depression and anxiety tend to be in agreement with international evidence. The urban characteristics shown to be associated with reduced NCD risk factors and morbidity in New Zealand studies include greater green space, street connectivity, safety, access to destinations/resources, dwelling density, aesthetics, and community cohesion; and lower residential mobility, and alcohol and tobacco outlet density. Findings also suggest that health-promoting urban environments may be particularly relevant for those who are more reliant on their local neighbourhood.

Conclusions

There is a rapidly growing body of literature exploring the relationships between the urban environment and health. Despite the limitations of using mostly observational data, recent evidence indicates that aspects of the physical (built and natural) and social environment that enable movement, provide destinations, and enhance day-to-day experiences in the urban setting, are associated with modestly improved NCD risk factors, and lower risk of some NCDs (**Figure 6**). Further, urban environments that incorporate these features are likely to be more equitable and inclusive. While this rapid evidence review has only considered the impact of the urban environment on a selection of NCD risk factors and morbidity, there are many potential co-benefits of designing urban areas that support NCD-related health, including environmental, economic, and other health outcomes (Giles-Corti et al., 2010; Macmillan et al., 2014; Public Health Advisory Committee, 2010; Sallis et al., 2015; Zapata-Diomedi et al., 2015). These findings reinforce the public health principle that creating and maintaining healthy environments should be a priority for primary disease prevention (Prüss-Ustün et al., 2016).

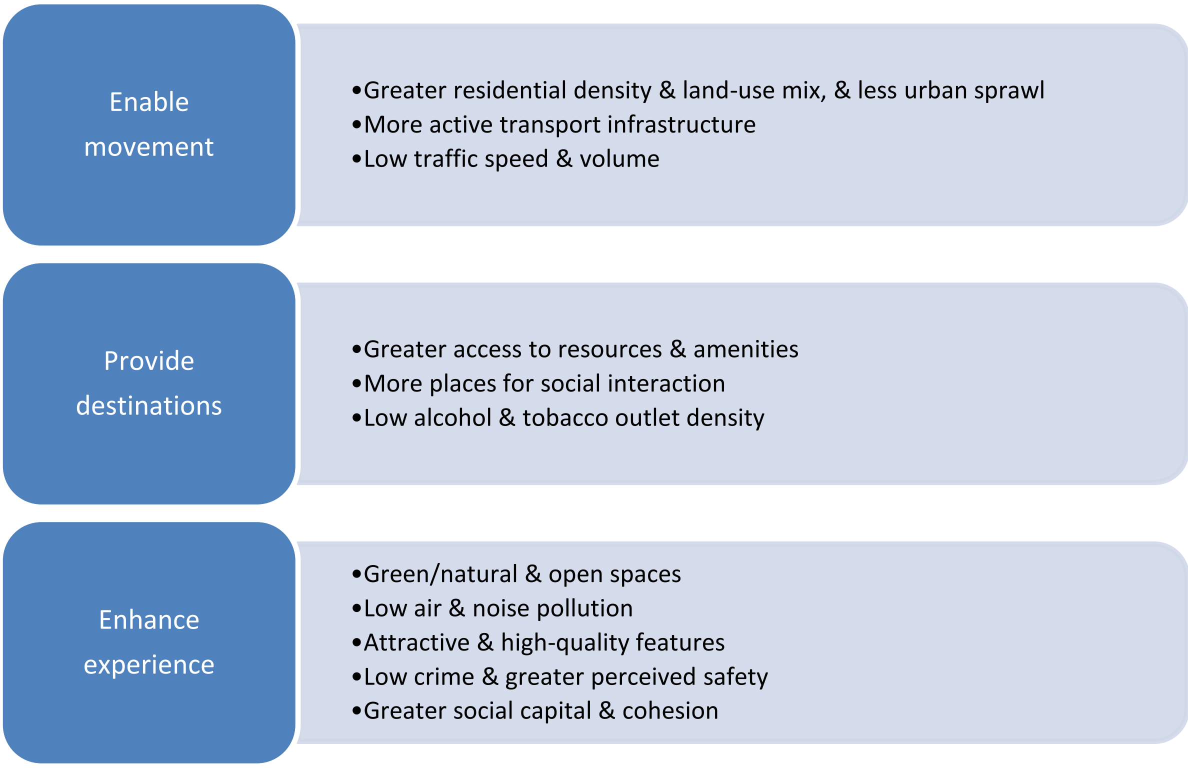

Figure 6. Urban characteristics that enable movement, provide destinations, and enhance the urban experience are most consistently associated with improved NCD risk factors and lower risk of chronic NCDs. (These general groupings are modified from those presented by Hooper and colleagues (2015b).)

As the identified health-promoting urban characteristics are modifiable to varying degrees, this creates an opportunity for intervention – either when upgrading existing areas or creating new spaces. Many organisations around the world have produced guidelines for designing urban areas that promote health (e.g. (Christchurch City Council, undated; London Healthy Urban Development

Unit, 2015; Ministry for the Environment, 2005; National Heart Foundation of Australia, Planning Institute Australia, & Australian Local Government Association, 2009; Ross & Chang, 2014; Sport England, Public Health England, & David Lock Associates, 2015; The New York City Departments of Design and Construction, 2010). The recommendations included in these guidelines align with the findings of this review and highlight the role of active transport facilities, aesthetics, connectivity, density, parks and green space, mixed land use, safety, and inclusivity in healthy urban design and planning. The documents also consistently highlight the need for multicomponent, comprehensive, and integrated urban systems.

Translating evidence into policy and practice is challenging, and the involvement of sectors beyond those responsible for health, including city and transport design and planning, property development, landscape architecture, road engineering, energy, and environmental protection, is integral to create healthy urban environments (Giles-Corti et al., 2015; Lowe, Boulange, & Giles-Corti, 2014; Prüss-Ustün et al., 2016; Public Health Advisory Committee, 2010). Using Health Impact Assessment within a Health in All Policies approach can assist with creating healthy urban environments through integrated planning - utilising collaborative approaches across the public and private sectors, and levels of government. Strategies that may further facilitate the translation of research evidence into health-promoting urban planning policy and practice include establishing links with policymakers and practitioners, working with knowledge brokers to facilitate effective communication, including economic analyses, and using natural experiments to evaluate the outcomes of policy decisions (Giles-Corti et al., 2015; Lowe et al., 2014).

The application of health-promoting urban design is particularly pertinent in Canterbury, where significant reconstruction is underway after the devastating earthquakes in 2010 and 2011. There is still great opportunity to further upgrade and develop medium-density, mixed-use, mixed-income neighbourhoods that are attractive, safe and sociable to promote good health for Cantabrians. This reconstruction also provides an ideal space to use pilot projects to trial new urban interventions that are sensitive to local circumstances (Rydin et al., 2012), that can be evaluated to further inform urban policy and planning in other parts of Aotearoa New Zealand.

Appendices

Appendix A: Summary tables of studies investigating associations between urban characteristics and non-communicable diseases

Table A1. Summary of *cross-sectional* studies investigating associations between *T2DM* prevalence and urban characteristics

Reference	Study location; type; n (participant age)	T2DM definition	Urban characteristic definition	Outcomes (OR or PR, 95% CI)*	Variables adjusted for in analyses
(Astell-Burt et al., 2014a)	New South Wales, Australia; random sample from universal medical insurance database; n=267,072 (>45yr)	Self-reported diabetes; previously diagnosed by a doctor; diabetes type not specified, but assumed to be T2DM	Green space within 1km of home (percentage of green space land use available; GIS). Quintiles (Q1 ≤20% green space, Q2 21-40%, Q3 41-60%, Q4 61-80%, Q5 ≥81%)	Overall trend, **p=0.002** Comparison of Q1 vs… Q2: OR 0.99, 95% CI 0.96-1.03 Q3: **OR 0.90, 95% CI 0.85-0.96** Q4: **OR 0.91, 95% CI 0.84-0.99** Q5: OR 0.94, 95% CI 0.85-1.03	Age, sex, couple status, ancestry, country of birth, language spoken at home, weight status, risk of psychological distress, smoking status, hypertension, diet, walking, physical activity, sitting time, economic status, annual income, qualifications, neighbourhood affluence, geographic remoteness
(Bodicoat et al., 2014)	Leicestershire, UK; 3 diabetes screening studies, participants without T2DM randomly selected from general practitioners; n=10,476 (mean 59yr)	Assessed at clinic visit; OGTT (fasting glucose ≥7.0mmol/L or 2hr glucose ≥1.1mmol/L) or HbA1c; ≥6.5%; 48mmol/mol.	Green space within 800m radius of home (percentage; GIS). Quartiles (≤30% green space, 31-59%, 60-77%, ≥78%)	Overall trend, p=0.990 Comparison of Q1 vs… Q2: OR 0.96, 95% CI 0.73-1.27 Q3: OR 0.98, 95% CI 0.72-1.32 Q4: OR 1.00, 95% CI 0.68-1.47	Ethnicity, age, sex, area social deprivation score, urban/rural status, BMI, physical activity, fasting glucose, 2hr glucose, total cholesterol
			Green space within 3km radius of home. Quartiles (as above)	Overall trend, **p=0.008** Comparison of Q1 vs… Q2: **OR 0.71, 95% CI 0.54-0.93** Q3: OR 0.76, 95% CI 0.54-1.05 Q4: **OR 0.53, 95% CI 0.35-0.82**	
			Green space within 5km radius of home. Quartiles (as above)	Overall trend, **p=0.041** Comparison of Q1 vs… Q2: **OR 0.65, 95% CI 0.50-0.85** Q3: OR 0.79, 95% CI 0.56-1.09 Q4: **OR 0.65, 95% CI 0.44-0.95**	

Reference	Study location; type; n (participant age)	T2DM definition	Urban characteristic definition	Outcomes (OR or PR, 95% CI)*	Variables adjusted for in analyses
			Green space within 800m road network of home. Quartiles (as above)	Overall trend, p=0.888 Comparison of Q1 vs… Q2: OR 1.07, 95% CI 0.82-1.40 Q3: OR 0.92, 95% CI 0.69-1.24 Q4: OR 1.03, 95% CI 0.73-1.45	
			Green space within 3km road network of home. Quartiles (as above)	Overall trend, **p=0.001** Comparison of Q1 vs… Q2: **OR 0.71, 95% CI 0.55-0.93** Q3: **OR 0.67, 95% CI 0.49-0.93** Q4: **OR 0.48, 95% CI 0.30-0.77**	
			Green space within 5km road network of home. Quartiles (as above)	Overall trend, **p=0.013** Comparison of Q1 vs… Q2: **OR 0.67, 95% CI 0.51-0.88** Q3: OR 0.75, 95% CI 0.54-1.05 Q4: **OR 0.58, 95% CI 0.39-0.86**	
(California Center for Public Health Advocacy, 2008a, 2008b)	California, USA; random-digit-dial telephone survey; n>43,000 (adults, specific age not stated)	Self-reported diabetes, previously diagnosed by a doctor	Ratio of fast food restaurants and convenience stores to grocery stores and produce vendors near home (Retail Food Environment Index; GIS). Tertiles (index <3, 3-4.9, ≥5)	Those living in areas with the highest ratio of unhealthy to healthy food vendors were 24% more likely to have been diagnosed with T2DM than those living in areas with the lowest ratio (other OR and 95% CI not reported)	Race/ethnicity, household income, age, gender, physical activity, and community income
(Maas et al., 2009)	The Netherlands; data from electronic medical records of 195 general practitioners over 1yr; n=343,103 (all ages)	Diagnosis of diabetes extracted from medical records	Green space within 1km radius of home (percentage; GIS)	**OR 0.98, 95% CI 0.97-0.99.** i.e. the annual prevalence for T2DM was 2% lower in areas with 10% more green space than average.	Gender, age, education, work status, healthcare insurance type, urbanicity
			Green space within 3km radius of home (percentage; GIS)	OR 0.98, 95% CI 0.97-1.00	
(Morland et al., 2006)	USA; random sample; n=10,763 (>49yr)	T2DM confirmed at a clinic visit; reported taking medications for diabetes, had glucose ≥200mg/dL, and/or 8-hr fasting glucose >126mg/dL.	Presence of nearby supermarkets in neighbourhood (yes/no; GIS)	PR 0.96, 95% CI 0.84-1.10	All types of food stores and service places, gender, race/ethnicity, age, income, education, and physical activity
			Presence of nearby grocery stores in neighbourhood (yes/no; GIS)	PR 1.11, 95% CI 0.99-1.24	
			Presence of nearby convenience stores in neighbourhood (yes/no; GIS)	PR 0.98, 95% CI 0.86-1.12	

Reference	Study location; type; n (participant age)	T2DM definition	Urban characteristic definition	Outcomes (OR or PR, 95% CI)*	Variables adjusted for in analyses
(Müller-Riemenschneider et al., 2013)	Western Australia; telephone survey of a stratified random sample; n=5,970 (≥25yr)	Self-reported; T2DM previously diagnosed by a doctor and/or receiving medication for T2DM	Walkability (index includes residential density, street connectivity and land-use mix; GIS) within 800m of home. Compare least to most walkable neighbourhoods	All: OR 0.79, 95% CI 0.52-1.21, p=2.82 Males: OR 0.60, 95% CI 0.32-1.14, p=0.122 Females: OR 0.97, 95% CI 0.54-1.73, p=0.917	Age, sex, education level, household income, marital status, physical activity, sedentary behaviour
			Walkability within 1,600m of home. Compare least to most walkable neighbourhoods	All: OR 1.08, 95% CI 0.72-1.62, p=0.701 Males: OR 1.26, 95% CI 0.72-2.21, p=0.425 Females: OR 0.92, 95% CI 0.51-1.66, p=0.779	
(Rachele et al., 2016)	Brisbane, Australia; random sample within 200 stratified neighbourhoods; n=11,035 (40-65yr)	Self-reported; T2DM previously diagnosed by a doctor	Neighbourhood socioeconomic advantage (using census-derived scores). Quintiles (20% least disadvantaged to 20% most disadvantaged)	Comparison of Q1 vs… Q2: OR 0.94, 95% CI 0.60-1.48 Q3: OR 1.35, 95% CI 0.87-2.08 Q4: **OR 1.93, 95% CI 1.30-2.92** Q5: **OR 1.81, 95% CI 1.15-2.83**	Age, sex, education, occupation, household income
(Villanueva et al., 2013)	Perth, Western Australia; stratified random sample; n=11,406 (≥25yr)	Self-reported diabetes; previously diagnosed by a doctor; diabetes type not specified, but assumed to be T2DM	Level of slope within 1,600m of home (mean; GIS). Continuous variable and tertiles (low, moderate, high slope)	Continuous: **OR 0.87, 95% CI 0.80-0.94.** i.e. for each 1% increase in mean slope, the odds of having T2DM was 13% lower. Comparison of T1 vs… T2: **OR 0.82, 95% CI 0.55-0.95.** T3: **OR 0.52, 95% CI 0.39-0.69**.	Age, gender, education, income, neighbourhood walkability, count of nearby destinations, fruit and vegetable intake, time spent walking

*Statistically significant associations **bolded**

BMI, body mass index; CI, confidence interval; GIS, Geographical Information System; HbA1c, glycated haemoglobin; HR, hazard ratio; n, number of participants; OGTT, oral glucose tolerance test; OR, odds ratio; PR, prevalence ratio; T2DM, type 2 diabetes mellitus; USA, United States of America; yr, years.

Table A2. Summary of *longitudinal* studies investigating associations between *T2DM* incidence and urban characteristics

Reference	Study location; type (year range); follow-up duration; n (participant age)	T2DM definition	Urban characteristic definition	Outcomes (OR, HR, or RR, 95% CI)*	Variables adjusted for in analyses
(Booth et al., 2013)	Toronto, Canada; retrospective cohort study (2005-2010); 5yr; n=214,882 recent immigrants and n=1,024,380 long-term residents (30-64yr at baseline)	Medical diabetes database records data, at least one hospitalization or at least two claims for physicians' services (within 2yr) with a diagnosis of diabetes	Walkability (validated index including population density, dwelling density, street connectivity, availability of walkable destinations (number of retail stores and services within a 10-minute walk). Quintiles (least to most walkable)	Comparisons of most vs least walkable neighbourhoods… Males, recent immigrants: **RR 1.58, 95% CI 1.42-1.75** Males, long-term residents:: **RR 1.32, 95% CI 1.26-1.38** Females, recent immigrants: **RR 1.67, 95% CI 1.48-1.88** Females, long-term residents:: **RR 1.24, 95% CI 1.18-1.31**	Age, area income
(Christine et al., 2015)	USA; population-based multi-ethnic cohort (2000-2012); median 8.9yr; n=5,124 (45-84yr at baseline)	Assessed clinically at five time points (fasting glucose ≥126mg/dL or use of insulin or oral anti-hyperglycaemics)	Availability of healthy food nearby (fresh fruit and vegetables in neighbourhood; survey scale)	**HR 0.88, 95% CI 0.78-0.98.** i.e. an IQR increase in exposure is associated with a 12% lower risk of developing T2DM	Age, sex, family history of T2DM, per capita household income, educational level, race/ethnicity, smoking status, alcohol consumption, neighbourhood SES
			Proximity to supermarkets and fruit/vegetable markets (number per square mile; GIS)	HR 1.01, 95% CI 0.96-1.07	
			Walking environment availability (neighbourhood offers many opportunities to be active; survey scale)	**HR 0.80, 95% CI 0.70-0.92**	
			Access to commercial recreational establishments (number per square mile; GIS)	HR 0.98, 95% CI 0.94-1.03	
			Neighbourhood social cohesion (people in neighbourhood can be trusted; survey scale)	HR 1.00, 95% CI 0.89-1.11	
			Neighbourhood safety (safety walking day or night; survey-based scales)	HR 0.96, 95% CI 0.82-1.11	
(Freedman et al., 2011)	USA; nationally representative sample cohort (2002-2004); 2yr; n=15,374 (≥55yr	Self-reported diabetes diagnosis from a doctor	Economic advantage (upper quartile of the % of owner-occupied housing units in the tract, % of families with a total annual income ≥$75000, % of adults with a college degree; census-derived)	Males: OR 0.97, 95% CI 0.75-1.25 Females: OR, 0.99 (0.80-1.22)	Age, race/ethnicity, marital status, region of residence, smoking status, education,

Reference	Study location; type (year range); follow-up duration; n (participant age)	T2DM definition	Urban characteristic definition	Outcomes (OR, HR, or RR, 95% CI)*	Variables adjusted for in analyses
	at baseline)		Economic disadvantage (% total population in poverty, % ≥65yr in poverty, % households receiving public assistance income, unemployment rate among ≥16yr, % housing units without a vehicle, % population Black; census-derived)	Males: OR 0.88, 95% CI 0.71-1.11 Females: OR 0.86, 95% CI 0.69-1.07	mean assets, income, childhood health, childhood SES, region of birth, and all neighbourhood scales
			Immigrant area (% of tract Hispanic, foreign-born, limited English skills, Hispanic isolation; census-derived)	Males: OR 1.01, 95% CI 0.80-1.28 Females: OR 0.82, 95% CI 0.66-1.02	
			Crime and segregation (crime occurrences per capita, Black isolation, Black–White dissimilarity; census-derived)	Males: OR 0.97, 95% CI 0.81-1.16 Females: OR 1.07, 95% CI 0.91-1.26	
			Residential stability (% in 2000 living in same house since at least 1995, and by median number of years of residence; census-derived)	Males: OR 0.97, 95% CI 0.82-1.15 Females: OR 1.15, 95% CI 0.99-1.33	
			Street connectivity (number of street segments per square mile, number of nodes per square mile, ratio of the number of complete loops to the maximum number of possible loops given the number of intersections, ratio of actual street segments to the maximum possible street segments; GIS)	Males: OR 1.06, 95% CI 0.86-1.29 Females: OR 1.01, 95% CI 0.84-1.20	
			Air pollution (quarterly measures of Particulate Matter of ≤10lm, and summertime ozone averages; air quality system)	Males: OR 0.96, 95% CI 0.80-1.16 Females: OR 0.88, 95% CI 0.74-1.04	
			Density (number of food stores, restaurants, and housing units per square mile and by tract-level population density; census-derived)	Males: OR 1.05, 95% CI 0.89-1.24 Females: OR 0.99, 95% CI 0.83-1.17	
(Jordan et al., 2014)	North Staffordshire, UK; survey follow-up; 3yr; n=18,047 (≥50yr at baseline)	New primary care consultation for diabetes (type not stated)	Deprivation score for geographical areas based on income, employment, health deprivation and disability, education, skills and training, barriers to housing and services, living environment, crime. Quintiles (least to most deprived)	Comparison of Q1 vs… Q2: OR 1.03, 95% CI 0.80-1.33 Q3: OR 1.04, 95% CI 0.80-1.35 **Q4: OR 1.41, 95% CI 1.06-1.87** **Q5: OR 1.51, 95% CI 1.09-2.09**	Age, gender, general practice, individual-level deprivation

Reference	Study location; type (year range); follow-up duration; n (participant age)	T2DM definition	Urban characteristic definition	Outcomes (OR, HR, or RR, 95% CI)*	Variables adjusted for in analyses
(Paquet et al., 2014)	South Australia; randomly-selected biomedical cohort (2000-2006); mean 3.5yr; n=3,145 (mean 51.5yr, SD 15.5, at baseline)	Assessed at clinic visits, pre-diabetes/diabetes, HbA1c ≥5.7% or fasting plasma glucose ≥5.6mmol/L, or diagnosed diabetes	Walkability (index constructed from dwelling density, intersection density, land use entropy – residential, commercial or recreation, retail footprint)	**RR 0.88, 95% CI 0.80-0.97, p=0.010.** i.e. a 1 SD increase in walkability index is associated with a 12% lower risk of developing T2DM	Gender, age, household income, education, area- level socioeconomic deprivation
			Public open space (>700m^2 used as sporting facilities, reserves, national parks, conservation reserves, botanic gardens; GIS) within 1km, size	**RR 0.75, 95% CI 0.69-0.83, p<0.0001**	
			Public open space within 1km, number	RR 1.00, 95% CI 0.92-1.08, p=0.93	
			Public open space within 1km, greenness	RR 1.01, 95% CI 0.90-1.13, p=0.89	
			Public open space within 1km, % associated with organised sport	RR 1.09, 95% CI 0.97-1.22, p=0.16	
			Relative healthfulness of food environment (ratio of fast food restaurants and unhealthy food stores to healthy food stores)	RR 0.99, 95% CI 0.90-1.09, p=0.88	
(White et al., 2016)	Sweden; quasi-experimental longitudinal study (1987-2010); n=61,386 (25-50yr at baseline)	New diagnosis of T2DM between 2002 and 2010, using ICD codes from inpatient, outpatient and prescription registers	Neighbourhood deprivation (small-area). 3 categories (low, moderate, high)	Comparison of low deprivation vs… moderate: **OR 1.15, 95% CI 1.01-1.31** high: **OR 1.22, 95% CI 1.07-1.38**	5-yr age categories, sex, educational attainment, marital status, region of initial placement, family size, region of origin, yr of arrival

*Statistically significant associations **bolded**

CI, confidence interval; GIS, Geographical Information System; HR, hazard ratio; ICD, International Classification of Diseases; IQR, inter-quartile range; n, number of participants; OR, odds ratio; RR, relative risk/risk ratio; SD, standard deviation; SES, socioeconomic status; T2DM, type 2 diabetes mellitus; UK, United Kingdom; USA, United States of America; yr, years.

Table A3. Summary of *cross-sectional* studies investigating associations between *CVD* prevalence and urban characteristics

Reference	Study location; type; n (participant age)	CVD definition	Urban characteristic definition	Outcomes (OR or RR, 95% CI)*	Variables adjusted for in analyses
(Maas et al., 2009)	The Netherlands; data from electronic medical records of 195 general practitioners over 1yr; n=343,103 (all ages)	Diagnosis of CHD extracted from medical records	Green space within 1km radius of home (percentage; GIS)	**OR 0.97, 95% CI 0.95-0.99**	Gender, age, education, work status, healthcare insurance type, urbanicity
			Green space within 3km radius of home (percentage; GIS)	OR 0.97, 95% CI 0.93-1.01	
		Diagnosis of cardiac disease extracted from medical records	Green space within 1km radius of home (percentage; GIS)	**OR 0.98, 95% CI 0.97-0.99**	
			Green space within 3km radius of home (percentage; GIS)	OR 1.00, 95% CI 0.93-1.01	
		Diagnosis of stroke or brain haemorrhage extracted from medical records	Green space within 1km radius of home (percentage; GIS)	OR 0.98, 95% CI 0.95-1.00	
			Green space within 3km radius of home (percentage; GIS)	OR 0.98, 95% CI 0.92-1.04	
(Morgenstern et al., 2009)	Texas, USA; n=1,247 (mean 72yr)	Ischaemic stroke, obtained from medical records	Number of fast food restaurants in the neighbourhood (census tract, GIS). Comparison of neighbourhoods in the 75th percentile to the 25th percentile.	Overall: **RR 1.01, 95% CI 1.00-1.01, p=0.02**. i.e. risk of stroke increased by 1% for every fast food restaurant in the neighbourhood **RR 1.13, 95% CI 1.02-1.25**	Age, gender, race/ethnicity, neighbourhood SES
(Pereira et al., 2012)	Western Australia; representative sample; n=11,404 (≥25yr)	Hospital admission for CHD or stroke	Variability in greenness (within 1.6km, GIS); Tertiles (low - predominantly green, moderate, high - predominantly non-green)	Overall: OR 0.82, 95% CI 0.68-1.00 Comparison of T1 vs… T2: OR 0.85, 95% CI 0.60-1.21 T3: **OR 0.63, 95% CI 0.43-0.92**	Age, sex, possession of a healthcare card, education, household income, non-gestational diabetes, BMI, hypertension, high cholesterol, fruit and vegetable intake, risky drinking, smoking, air quality proxy
			Mean greenness (within 1.6km, GIS); Tertiles (low, moderate, high)	Overall: OR 0.90, 95% CI 0.77-1.05 Comparison of T1 vs… T2: OR 0.90, 95% CI 0.63-1.21 T3: OR 0.87, 95% CI 0.60-1.27	
		Self-reported prior medical diagnosis of CHD or stroke	Variability in greenness (within 1.6km, GIS); Tertiles (low, moderate, high)	Overall: OR 0.91, 95% CI 0.82-1.02 Comparison of T1 vs… T2: **OR 0.76, 95% CI 0.62-0.94** T3: OR 0.84, 95% CI 0.68-1.03	
			Mean greenness (within 1.6km, GIS); Tertiles (low, moderate, high)	Overall: OR 0.93, 95% CI 0.85-1.01 Comparison of T1 vs… T2: OR 0.84, 95% CI 0.69-1.02 T3: OR 0.94, 95% CI 0.76-1.15	

Reference	Study location; type; n (participant age)	CVD definition	Urban characteristic definition	Outcomes (OR or RR, 95% CI)*	Variables adjusted for in analyses
(Pindus et al., 2015)	Estonia; cross-sectional surveys within cohort study; in 2000-2001, n=1,708) and in 2011-2012, n=1,370 (25-50yr at start of cohort study)	Self-reported prior diagnosis of cardiac disease	Living within 150m of roads with high total traffic (i.e. ≥10,000 vehicles/day; GIS)	In 2000-2001: **OR 1.91, 95% CI 1.15-3.16** In 2011-2012: **OR 1.58, 95% CI 1.01-2.47**	In 2000-2001: Age, education In 2011-2012: Age, smoking history
			Living within 150m of roads with ≥250 heavy duty vehicles/day (GIS)	In 2000-2001: **OR 1.49, 95% CI 1.09-2.04** In 2011-2012: OR 1.00, 95% CI 0.68-1.46	In 2000-2001 and 2011-2012: Age
			Living within 150m of roads with ≥500 heavy duty vehicles/day (GIS)	In 2000-2001: **OR 1.52, 95% CI 1.04-2.24** In 2011-2012: OR 1.37, 95% CI 0.87-2.16	In 2000-2001: Age In 2011-2012: Age, smoking history
(Rachele et al., 2016)	Brisbane, Australia; random sample within 200 stratified neighbourhoods; n=11,035 (40-65yr)	Self-reported heart disease previously diagnosed by a doctor	Neighbourhood socioeconomic advantage (using census-derived scores). Quintiles (20% least disadvantaged to 20% most disadvantaged)	Comparison of Q1 vs… Q2: OR 1.00, 95% CI 0.73-1.39 Q3: OR 0.96, 95% CI 0.69-1.35 Q4: OR 0.97, 95% CI 0.71-1.34 Q5: OR 1.26, 95% CI 0.90-1.78	Age, sex, education, occupation, household income
(Richardson et al., 2013)	New Zealand; national survey; n=8,158 (≥15yr)	Self-reported previous diagnosis of a heart attack, stroke, angina, heart failure or other heart disease	Green space availability (proportion of green space in each census area unit; GIS). Quartiles (<15.7%, 15.7-33.2%, 33.3-69.8%, >69.8%)	Comparison of Q1 vs… Q2: **OR 0.82, 95% CI 0.67-1.00** Q3: **OR 0.80, 95% CI 0.64-0.99** Q4: OR 0.84, 95% CI 0.65-1.08	Sex, age group, smoking behaviour, individual socioeconomic deprivation, stratum, number of respondents in meshblock, number of adults in household, ethnicity
(Selander et al., 2009)	Stockholm County, Sweden; population-based case-control study; n=3,666 (45-70yr)	Myocardial infarction, data from hospital records	Long-term levels of road traffic noise (i.e. ≥50 A-weighted decibels; objectively measured)	**OR 1.38, 95% CI 1.11-1.71**	Age, sex, catchment area, diabetes, physical inactivity, smoking, air pollution, occupational noise exposure

*Statistically significant associations **bolded**

BMI, body mass index; CHD, coronary heart disease; CI, confidence interval; GIS, Geographical Information System; n, number of participants; OR, odds ratio; RR, risk ratio; USA, United States of America; yr, years.

Table A4. Summary of *longitudinal* studies investigating associations between *CVD* incidence and urban characteristics

Reference	Study location; type (year range); follow-up duration; n (participant age)	CVD definition	Urban characteristic definition	Outcomes (OR or HR, 95% CI)*	Variables adjusted for in analyses
(Freedman et al., 2011)	USA; national sample (2002-2004); 2yr; n=10,459 (≥55yr)	Self-reported medical diagnosis of heart problems: CHD, angina, congestive heart failure, or other heart problems	Economic advantage (see definition in Table A2)	Males: OR 0.94, 95% CI 0.80-1.12 Females: OR 0.95	Age, race/ethnicity, marital status, region of residence, smoking status, education, mean assets, income, childhood health, childhood SES, region of birth, and all neighbourhood scales
			Economic disadvantage (see definition in Table A2)	Males: OR 0.98, 95% CI 0.79-1.22 Females: **OR 1.20, 95% CI 1.00-1.43, p<0.05**	
			Immigrant area (see definition in Table A2)	Males: OR 1.00, 95% CI 0.82-1.22 Females: OR 1.04, 95% CI 0.87-1.24	
			Crime and segregation (see definition in Table A2)	Males: OR 1.01, 95% CI 0.87-1.17 Females: OR 1.06, 95% CI 0.93-1.22	
			Residential stability (see definition in Table A2)	Males: OR 0.97, 95% CI 0.85-1.12 Females: OR 0.99, 95% CI 0.87-1.12	
			Street connectivity (see definition in Table A2)	Males: OR 1.05, 95% CI 0.89-1.23 Females: OR 0.90, 95% CI 0.77-1.05	
			Air pollution (see definition in Table A2)	Males: OR 1.06, 95% CI 0.90-1.24 Females: OR 0.97, 95% CI 0.84-1.12	
			Density (see definition in Table A2)	Males: OR 1.03, 95% CI 0.91-1.16 Females: OR 0.95, 95% CI 0.83-1.09	
(Freedman et al., 2011)	USA; national sample (2002-2004); 2yr; n=10,459 (≥55yr)	Self-reported medical diagnosis of stroke	Economic advantage (see definition in Table A2)	Males: OR 0.92, 95% CI 0.70-1.21 Females: OR 0.85, 95% CI 0.66-1.08	Age, race/ethnicity, marital status, region of residence, smoking status, education, mean assets, income, childhood health, childhood SES, region of birth, and all neighbourhood scales
			Economic disadvantage (see definition in Table A2)	Males: OR 0.81, 95% CI 0.57-1.14 Females: OR 0.78, 95% CI 0.60-1.02	
			Immigrant area (see definition in Table A2)	Males: OR 1.11, 95% CI 0.83-1.49 Females: OR 1.08, 95% CI 0.85-1.37	
			Crime and segregation (see definition in Table A2)	Males: OR 1.05, 95% CI 0.84-1.32 Females: OR 1.16, 95% CI 0.96-1.40	
			Residential stability (see definition in Table A2)	Males: OR 1.02, 95% CI 0.82-1.27 Females: OR 0.95, 95% CI 0.80-1.13	
			Street connectivity (see definition in Table A2)	Males: OR 0.89, 95% CI 0.68-1.17 Females: OR 1.02, 95% CI0.83-1.25	
			Air pollution (see definition in Table A2)	Males: OR 1.04, 95% CI 0.81-1.34 Females: OR 0.93, 95% CI 0.77-1.13	
			Density (see definition in Table A2)	Males: OR 1.06, 95% CI 0.89-1.26 Females: OR 1.10, 95% CI 0.96-1.27	

Reference	Study location; type (year range); follow-up duration; n (participant age)	CVD definition	Urban characteristic definition	Outcomes (OR or HR, 95% CI)*	Variables adjusted for in analyses
(Griffin et al., 2013)	USA; clinical cohort study (1993-2005); mean 7.5yr; n=45,376 females (50-79yr at baseline)	CHD event (CHD death, MI, angina, coronary revascularisation), self-reported or from medical documents	Urban compactness (index reflecting: residential density, land-use mix, street connectivity, centredness)	**HR 0.95, 95% CI 0.91-0.99**	Age group, yr enrolled, race/ethnicity, education, income, marital status, family history of MI, study arm, neighbourhood SES, BMI, waist-to-hip ratio, self-reported history of diabetes, hyperlipidaemia medication use and/or high cholesterol, hypertension, smoking pack-years, alcohol use, weekly calorie expenditure, hormone use.
			Residential density (gross and net densities and proportions of populations living at different densities; index)	**HR 0.94, 95% CI 0.91-0.97**	
			Land-use mix (mix of homes, jobs, services; index)	HR 0.99, 95% CI 0.94-1.04	
			Street connectivity (lengths and size of blocks; index)	HR 0.98, 95% CI 0.94-1.02	
			Centredness (degree to which development is focussed on the region's core; index)	HR 0.95, 95% CI0.91-1.00	
(Griffin et al., 2013)	USA; clinical cohort study (1993-2005); mean 7.5yr; n=45,376 females (50-79yr at baseline)	CHD death or MI, self-reported or from medical documents	Urban compactness (see definition above)	**HR 0.92, 95% CI 0.86-0.98**	See variables above
			Residential density (see above)	**HR 0.90, 95% CI 0.86-0.95**	
			Land-use mix (see above)	**HR 0.90, 95% CI 0.84-0.97**	
			Street connectivity (see above)	HR 0.95, 95% CI 0.89-1.01	
			Centredness (see above)	HR 0.98, 95% CI 0.91-1.05	
(Jordan et al., 2014)	North Staffordshire, UK; survey follow-up; 3yr; n=18,047 (≥50yr at baseline)	New primary care consultation for ischaemic heart disease	Deprivation score for geographical areas based on income, employment, health deprivation and disability, education, skills and training, barriers to housing and services, living environment, crime. Quintiles (least to most deprived)	Comparison of Q1 vs… Q2: OR 1.18, 95% CI 0.94-1.49 **Q3: OR 1.29, 95% CI 1.04-1.62** **Q4: OR 1.42, 95% CI 1.11-1.81** **Q5: OR 1.86, 95% CI 1.42-2.42**	Age, gender, general practice, individual-level deprivation
(Kawakami et al., 2011)	Sweden; nationwide study (2005-2007); 2yr; n=2,165,000 (35-80yr)	Hospitalisation for CHD (morbidity and mortality)	Presence of fast food restaurants in neighbourhood (yes/no; GIS)	Males: OR 1.00, 95% CI 0.97-1.02 Females: OR 1.00, 95% CI 0.96-1.04	Age, family income, neighbourhood-level deprivation
			Presence of bars/pubs in neighbourhood (yes/no; GIS)	Males: OR 0.99, 95% CI 0.95-1.04 Females: OR 1.02, 95% CI 0.96-1.08	
			Presence of physical activity facilities in neighbourhood (yes/no; GIS)	Males: OR 1.00, 95% CI 0.97-1.03 Females: OR 1.03, 95% CI 0.99-1.08	
			Presence of health care facilities in neighbourhood (yes/no; GIS)	Males: OR 1.02, 95% CI 0.99-1.05 Females: OR 1.01, 95% CI 0.97-1.05	

Reference	Study location; type (year range); follow-up duration; n (participant age)	CVD definition	Urban characteristic definition	Outcomes (OR or HR, 95% CI)*	Variables adjusted for in analyses
(Kawakami et al., 2011)	Sweden; nationwide study (2005-2007); 2yr; n=2,165,000 (35-80yr)	Hospitalisation for CHD (morbidity and mortality)	Presence of fast food restaurants within 1km radius (yes/no; GIS)	Males: OR 1.00, 95% CI 0.99-1.05 Females: OR 0.99, 95% CI 0.95-1.04	Age, family income, neighbourhood-level deprivation
			Presence of bars/pubs within 1km radius od (yes/no; GIS)	Males: OR 1.00, 95% CI 0.96-1.03 Females: OR 0.98, 95% CI 0.94-1.03	
			Presence of physical activity facilities within 1km radius (yes/no; GIS)	Males: OR 1.00, 95% CI 0.97-1.03 Females: OR 0.98, 95% CI 0.94-1.02	
			Presence of health care facilities within 1km radius (yes/no; GIS)	Males: OR 1.02, 95% CI 0.99-1.05 Females: OR 1.03, 95% CI 0.99-1.08	
(Kershaw et al., 2015)	USA; cohort study; mean 10.2yr; n=6,105 (45-84yr)	Non-fatal MI, resuscitated cardiac arrest, CHD death	Neighbourhood-level stressors (survey-based, combined, safety and violence, social cohesion – mutual trust and solidarity with neighbours, aesthetic quality – noise, litter and attractiveness). Tertiles (low, medium, high)	Overall, p=0.43 Comparison of T1 vs… T2: **HR 1.50, 95% CI 1.07-2.10** T3: HR 1.21, 95% CI 0.79-1.84	Age, gender, race/ethnicity, education, income, marital status, field centre, neighbourhood poverty, total cholesterol, lipid-lowering medication use, systolic blood pressure, blood pressure-lowering medication use, diabetes, BMI, physical activity, alcohol use, smoking status, individual stressors (financial, job, relationship or health-related problems)
(Pindus et al., 2015)	Estonia; cohort study (2000-2012); 11yr; n=1,370 (25-50yr)	Self-reported prior diagnosis of cardiac disease	Living within 150m of roads with high total traffic (i.e. ≥10,000 vehicles/day; GIS)	**OR 2.02, 95% CI 1.07-3.80**	Age, smoking history
			Living within 150m of roads with ≥250 heavy duty vehicles/day (GIS)	OR 1.08, 95% CI 0.59-1.98	
			Living within 150m of roads with ≥500 heavy duty vehicles/day (GIS)	OR 1.19, 95% CI 0.59-2.39	

*Statistically significant associations **bolded**

BMI, body mass index; CHD, coronary heart disease; CI, confidence interval; HR, hazard ratio; GIS, Geographical Information System; MI, myocardial infarction; n, number of participants; OR, odds ratio; SES, socioeconomic status; UK, United Kingdom; USA, United States of America; yr, years.

Table A5. Summary of *cross-sectional* studies investigating associations between *depression and anxiety* and urban characteristics

Reference	Study location; type; n (participant age)	Depression/anxiety definition	Urban characteristic definition	Outcomes (OR or IRR, 95% CI)*	Variables adjusted for in analyses
(Maas et al., 2009)	The Netherlands; data from 195 general practitioners over 1yr; n=343,103 (all ages)	Depression, diagnosis sourced from electronic medical records	Green space within 1km radius of home (percentage; GIS)	**OR 0.96, 95% CI 0.95-0.98**	Gender, age, education, work status, healthcare insurance type, urbanicity
			Green space within 3km radius of home (percentage; GIS)	OR 0.98, 95% CI 0.96-1.00	
		Anxiety disorder, diagnosis sourced from electronic medical records	Green space within 1km radius of home (percentage; GIS)	**OR 0.95, 95% CI 0.94-0.97**	
			Green space within 3km radius of home (percentage; GIS)	**OR 0.96, 95% CI 0.93-0.99**	
(Nutsford et al., 2013)	Auckland, New Zealand; 2008-2009 data collated from Ministry of Health; n=319,521 (≥15yr)	Anxiety/mood disorder treatment counts	Nearest useable green space (distance; GIS)	IRR **1.35, 95% CI 1.02-1.79, p=0.033**	Age, neighbourhood deprivation
			Nearest total green space (distance; GIS)	IRR 1.3, 95% CI 0.95-1.79, p=0.107	
			Total green space within 300m (proportion; GIS)	IRR 1.00, 95% CI 1.00-1.01, p=0.449	
			Total green space within 3km (proportion; GIS)	IRR **0.96, 95% CI 0.94-0.97, p<0.001**	
			Useable green space within 300m (proportion; GIS)	IRR 1.00, 95% CI 1.00-1.01, p=0.360	
			Useable green space within 3km (proportion; GIS)	IRR **0.96, 95% CI 0.95-1.68, p<0.001**	
(Pereira et al., 2013)	Perth, Australia; population representative sample; n=6,837 (≥18yr)	Self-reported prior medical diagnosis of anxiety, stress or depression	Number of off-licence alcohol outlets within 1.6km area of home	OR 1.56, 95% CI 0.98-2.49, p=0.059	Age, sex, education, household income
		Hospital admission, outpatient or emergency contact for anxiety, stress or depression within previous 3-yr period	Number of off-licence alcohol outlets within 1.6km area of home	OR 1.07, 95% CI 0.92-1.24, p=0.400	

*Statistically significant associations **bolded**

CI, confidence interval; GIS, Geographical Information System; IRR, incidence rate ratio; n, number of participants; OR, odds ratio; yr, years.

Table A6. Summary of *cross-sectional* studies investigating associations between *cancer* and urban characteristics

Reference	Study location; type; n (participant age)	Cancer definition	Urban characteristic definition	Outcomes (OR or HR, 95% CI)*	Variables adjusted for in analyses
(Astell-Burt et al., 2014b)	New South Wales, Australia; cross-sectional; n=267,072 (≥45yr)	Self-reported medical diagnosis of skin cancer (melanoma and non-melanoma)	Green space within 1km radius of home, available for public use (percentage; GIS). Quintiles (≤20%, 21-40%, 41-60%, 61-80%, >80%)	Comparison of Q1 vs… Q2: **OR 1.06, 95% CI 1.04-1.09, p<0.001** Q3: **OR 1.09, 95% CI 1.05-1.14, p<0.001** Q4: **OR 1.11, 95% CI 1.05-1.17, p<0.001** Q5: **OR 1.09, 95% CI 1.02-1.16, p<0.001**	Age, gender, couple status, weight status, experience of psychological distress, smoking status, employment status, annual income, education qualifications, local affluence, geographic remoteness, ancestry, country of birth, language spoken at home, skin colour, tanning response, time spent outdoors, physical activity
(Bauer et al., 2013)	Georgia, USA; case-referent; n=47,817	Breast cancer diagnosis recorded in cancer registry	Outdoor light at night (average for years prior to diagnosis since 1992; satellite imagery data). Tertiles (lowest to highest exposure)	Comparison of T1 vs… T2: OR 1.06, 95% CI 0.97-1.16 T3: **OR 1.12, 95% CI 1.04-1.20, p<0.05**	Race, tumour grade and stage, year of diagnosis, age at diagnosis, area, area birth rate, area population mobility, population over 16 in the labour force, smoking prevalence
(Hurley et al., 2014)	California, USA; prospective cohort of female teachers; n=106,731	Self-reported or medical record diagnosis of invasive breast cancer	Outdoor light at night (2006 average; satellite imagery data). Quintiles (lowest to highest exposure)	Overall, p=0.06 Comparison of Q1 vs… Q2: HR 1.05, 95% CI 0.95-1.16 Q3: HR 1.06, 95% CI 0.95-1.17 Q4: HR 1.05, 95% CI 0.95-1.17 Q5: HR 1.12, 95% CI 1.00-1.26	Age, race/birthplace, family history of breast cancer, age at menarche, pregnancy history, breastfeeding history, physical activity, BMI, alcohol intake, menopausal status/HRT use, smoking status, smoking pack-years, neighbourhood SES, urbanisation
(Maas et al., 2009)	The Netherlands; cross-sectional data from 195 general practitioners; n=343,103 (all ages)	Cancer diagnosis (type not specified) extracted from medical records	Green space within 1km radius of home (percentage; GIS)	OR 1.00, 95% CI 0.98-1.02	Gender, age, education, work status, healthcare insurance type, urbanicity
			Green space within 3km radius of home (percentage; GIS)	OR 0.99, 95% CI 0.95-1.03	

*Statistically significant associations **bolded**

BMI, body mass index; CI, confidence interval; GIS, Geographical Information System; HR, hazard ratio; HRT, hormone replacement therapy; n, number of participants; OR, odds ratio; SES, socioeconomic status; USA, United States of America; yr, years.

Table A7. Summary of *longitudinal* studies investigating associations between *cancer* and urban characteristics

Reference	Study location; type (year range); follow-up duration; n (participant age)	Cancer definition	Urban characteristic definition	Outcomes (OR, 95% CI)*	Variables adjusted for in analyses
(Freedman et al., 2011)	USA; national sample longitudinal (2002-2004); 2yr; n=12,000 (≥55yr)	Self-reported medical diagnosis of cancer or malignant tumour (excluding minor skin cancers)	Economic advantage (see definition in Table A2)	Males: OR 1.04, 95% CI 0.86-1.26 Females: OR 0.92, 95% CI 0.74-1.15	Age, race/ethnicity, marital status, region of residence, smoking status, education, mean assets, income, childhood health, childhood SES, region of birth, and all neighbourhood scales
			Economic disadvantage (see definition in Table A2)	Males: OR 1.17, 95% CI 0.91-1.50 Females: OR 1.16, 95% CI 0.89-1.52	
			Immigrant area (see definition in Table A2)	Males: OR 0.77, 95% CI 0.59-1.01 Females: OR 0.89, 95% CI 0.66-1.19	
			Crime and segregation (see definition in Table A2)	Males: **OR 1.31, 95% CI 1.10-1.56, p<0.01** Females: **OR 1.25, 95% CI 1.04-1.52, p<0.05**	
			Residential stability (see definition in Table A2)	Males: OR 1.01, 95% CI 0.86-1.20 Females: OR 1.09, 95% CI 0.91-1.31	
			Street connectivity (see definition in Table A2)	Males: OR 0.94, 95% CI 0.77-1.15 Females: OR 0.82, 95% CI 0.66-1.01	
			Air pollution (see definition in Table A2)	Males: OR 0.93, 95% CI 0.78-1.11 Females: OR 0.85, 95% CI 0.70-1.03	
			Density (see definition in Table A2)	Males: OR 1.04, 95% CI 0.88-1.21 Females: OR 1.00, 95% CI 0.82-1.23	

*Statistically significant associations **bolded**

CI, confidence interval; n, number of participants; OR, odds ratio; SES, socioeconomic status; USA, United States of America; yr, years.

Table A8. Summary of *cross-sectional* investigating associations between *arthritis* and urban characteristics

Reference	Study location; type (year range); follow-up duration; n (participant age)	Arthritis definition	Urban characteristic definition	Outcomes (OR, 95% CI)*	Variables adjusted for in analyses
(Brennan et al., 2012)	Brisbane, Australia; cross-sectional random sample within 200 stratified neighbourhoods (2007); n=10,757 (40-65yr)	Self-reported medical diagnosis of arthritis	Neighbourhood advantage (census-based composite index). Quintiles (least to most disadvantaged)	Comparison of Q1 vs… Q2: OR 1.09, 95% CI 0.94-1.26 Q3: **OR 1.23, 95% CI 1.05-1.43** Q4: OR 1.17, 95% CI 0.99-1.38 Q5: **OR 1.42, 95% CI 1.20-1.68**	Sex, age, household income, education, occupation
(Maas et al., 2009)	The Netherlands; cross-sectional data from 195 general practitioners (2001); 1yr; n=343,103 (all ages)	Arthritis diagnosis extracted from medical records	Green space within 1km radius of home (percentage; GIS)	OR 0.99, 95% CI 0.97-1.01	Gender, age, education, work status, healthcare insurance type, urbanicity
			Green space within 3km radius of home (percentage; GIS)	OR 1.00, 95% CI 0.96-1.04	
		Osteoarthritis diagnosis extracted from medical records	Green space within 1km radius of home (percentage; GIS)	OR 0.97, 95% CI 0.93-1.01	
			Green space within 3km radius of home (percentage; GIS)	OR 0.97, 95% CI 0.92-1.03	

*Statistically significant associations **bolded**

CI, confidence interval; GIS, Geographical Information System; n, number of participants; OR, odds ratio; SES, socioeconomic status; USA, United States of America; yr, years.

Table A9. Summary of *longitudinal* studies investigating associations between *arthritis* and urban characteristics

Reference	Study location; type (year range); follow-up duration; n (participant age)	Arthritis definition	Urban characteristic definition	Outcomes (OR, 95% CI)*	Variables adjusted for in analyses
(Jordan et al., 2014)	North Staffordshire, UK; survey follow-up; 3yr; n=18,047 (≥50yr at baseline)	New primary care consultation for osteoarthritis / joint pain	Deprivation score for geographical areas based on income, employment, health deprivation and disability, education, skills and training, barriers to housing and services, living environment, crime. Quintiles (least to most deprived)	Comparison of Q1 vs… Q2: OR 0.94, 95% CI 0.84-1.05 Q3: OR 1.03, 95% CI 0.92-1.17 Q4: OR 1.11, 95% CI 0.97-1.27 Q5: OR 1.15, 95% CI 0.99-1.34	Age, gender, general practice, individual-level deprivation
(Freedman et al., 2011)	USA; national sample longitudinal (2002-2004); 2yr; n=5,511 (≥55yr)	Self-reported medical diagnosis of arthritis or rheumatism	Economic advantage (see definition in Table A2)	Males: OR 1.05, 95% CI 0.90-1.22 Females: OR 0.99, 95% CI 0.87-1.13	Age, race/ethnicity, marital status, region of residence, smoking status, education, mean assets, income, childhood health, childhood SES, region of birth, and all neighbourhood scales
			Economic disadvantage (see definition in Table A2)	Males: OR 1.08, 95% CI 0.88-1.33 Females: OR 1.04, 95% CI 0.86-1.25	
			Immigrant area (see definition in Table A2)	Males: OR 0.90, 95% CI 0.73-1.09 Females: OR 0.93, 95% CI 0.78-1.12	
			Crime and segregation (see definition in Table A2)	Males: OR 0.91, 95% CI 0.79-1.05 Females: OR 1.07, 95% CI 0.94-1.21	
			Residential stability (see definition in Table A2)	Males: OR 0.98, 95% CI 0.86-1.12 Females: OR 1.10, 95% CI0.97-1.23	
			Street connectivity (see definition in Table A2)	Males: OR 1.14, 95% CI 0.97-1.34 Females: OR 0.90, 95% CI 0.78-1.04	
			Air pollution (see definition in Table A2)	Males: OR 1.09, 95% CI 0.94-1.26 Females: OR 1.10, 95% CI 0.97-1.25	
			Density (see definition in Table A2)	Males: OR 0.94, 95% CI 0.79-1.13 Females: OR 1.05, 95% CI 0.95-1.16	

*Statistically significant associations **bolded**

CI, confidence interval; n, number of participants; OR, odds ratio; SES, socioeconomic status; UK, United Kingdom; USA, United States of America; yr, years.

Table A10. Summary of *systematic reviews and random effects model meta-analyses* investigating associations between *T2DM* and outdoor air pollution

Reference	n (study type); locations (years included in review)	T2DM definition	Air pollutant (exposure)	Studies included in meta-analysis. Estimate (HR, RR or MMR, 95% CI)*	Meta-analysis statistics
(Balti et al., 2014)	n=10 (5 cross-sectional, 5 cohort); USA, Canada, Europe (to September 2013)	Self-reported diagnosed or based on ICD codes	NO_2 and NO_x (1 day-10yr)	3 cohort. Per 10μg/m^3 increase in exposure: **HR 1.13, 95% CI 1.04-1.22, p<0.001** 2 cross-sectional. Per 10μg/m^3 increase in exposure: **HR 1.16, 95% CI 1.00-1.35, p<0.001**	I^2=36.4%, p=0.208 I^2=23.2%, p=0.254
			$PM_{2.5}$ (1 day-10yr)	5 cohort. Per 10μg/m^3 increase in exposure: **HR 1.11, 95% CI 1.03-1.20, p<0.001**	I^2=0.0%, p=0.827
(Eze et al., 2015)	n=8 (5 longitudinal, 2 cross-sectional, 1 ecologic); Europe, USA (to April 2014)	Physician-diagnosed or antidiabetic medication use	NO_2 (long-term)	2 cohort and 2 cross-sectional. Per 10μg/m^3 increase in exposure: RR 1.08, 95% CI 1.00-1.17	I^2=58.4%, p=0.025
			$PM_{2.5}$ (long-term)	3 cohort. Per 10μg/m^3 increase in exposure: **RR 1.10, 95% CI 1.01-1.18**	I^2=0.0%, p=0.473
(Janghorbani et al., 2014)	n=17 (2 cross-sectional, 3 time-series, 6 case-crossover, 6 cohort); USA, Canada, Europe, Asia (to January 2013)	Not reported	NO_2	2 cross-sectional, 2 time-series, 4 cohort, 1 case-crossover: **RR or MMR 1.05, 95% CI 1.02-1.08, p=0.002**	I^2=71.9%, p<0.001
			O_3	1 time-series, 1 cohort, 2 case-crossover: **RR or MMR 1.07, 95% CI 1.05-1.09, p=0.000**	I^2=0.0%, p=0.961
			$PM_{2.5}$	2 time-series, 2 cohort: RR or MMR 1.05, 95% CI 0.99-1.01, p=0.093	I^2=43.0%, p=0.151
			PM_{10}	1 time-series, 1 cohort, 2 case-crossover: **RR or MMR 1.01, 95% CI 1.00-1.01, p=0.001**	I^2=0.0%, p=0.582
			SO_2	2 time-series: RR or MMR 1.05, 95% CI 0.97-1.14, p=0.239	Not reported
			SO_4	1 time-series, 1 case-crossover: **RR or MMR 1.05, 95% CI 1.01-1.08, p=0.007**	Not reported
			NO_2, O_3, SO_2, SO_4	2 cross-sectional, 2 time-series, 5 cohort, 4 case-crossover studies: **RR or MMR 1.05, 95% CI 1.03-1.07**	I^2=69.7%, p<0.001
			NO_2, O_3, SO_2, SO_4, $PM_{2.5}$,PM_{10}	2 cross-sectional, 3 time-series, 6 cohort, 6 case-crossover: **RR or MMR 1.03, 95% CI 1.02-1.05**	I^2=76.5%, p<0.001
(Park et al., 2014)	n=19 (4 cross-sectional, 7 ecological, 8 prospective); Europe, Canada, USA, Asia (to December 2013)	Not reported	O_3 (short-term, 0-7 days)	4 cohort. Per 10μg/m^3 increase in exposure: **HR 1.11, 95% CI 1.03-1.19**	Q_{df}=1.08, p=0.78
(Wang et al., 2014)	n=44 (cohort); USA, Canada, Europe (to June 2014)	Diagnosis using OGTT and/or fasting plasma glucose concentration, or local criteria	$PM_{2.5}$ (long-term, ≥3yr)	5 cohort. Per 10μg/m^3 or IQR increase in exposure: **RR 1.28, 95% CI 1.06-1.55, p=0.009** 5 studies. Standardised: **RR 1.39, 95% CI 1.14-1.68, p=0.009**	I^2=83.5%, p=0.000 I^2=86.3%, p=0.000
			PM_{10} (long-term, ≥3yr)	3 cohort. Per IQR increase in exposure: **RR 1.15, 95% CI 1.02-1.30, p=0.022** 4 cohort. Standardised: **RR 1.34, 95% CI 1.22-1.47, p<0.001**	I^2=0.0%, p=0.816 I^2=0.0%, p=0.799
			NO_2 (long-term, ≥3yr)	4 cohort. Per IQR increase in exposure: **RR 1.12, 95% CI 1.02-1.23, p=0.015** 6 cohort. Standardised: **RR 1.11, 95% CI 1.07-1.16, p<0.001**	I^2=63.5%, p=0.042 I^2=43.6%, p=0.114

*Statistically significant associations **bolded**

CI, confidence interval; CO, carbon monoxide; ICD, International Classification of Diseases; IQR, inter-quartile range; HR, hazard ratio; MMR, mortality rate ratio; n, number of studies included; NO_x, nitrogen oxides; NO_2, nitrogen dioxide; O_3; ozone; OGTT, oral glucose tolerance test; RR, risk ratio; SO_2, sulphur dioxide; USA, United States of America; yr, years.

Table A11. Summary of *systematic reviews and random effects model meta-analyses* investigating associations between *CVD* and short-term exposure (0-7 days) to outdoor air pollution

Reference	n (study type); study locations (years included in review)	CVD outcome definition	Air pollutant	Studies included in meta-analysis. Estimate (OR or RR, 95% CI)*	Meta-analysis statistics
(Luo et al., 2015)	n=31 (12 time-series and 19 case-crossover); Europe, USA, Asia, Australia, South America (to January 2015)	Myocardial infarction	$PM_{2.5}$	19 studies. Per 10µg/m^3 increase in exposure: **OR 1.02, 95% CI 1.02-1.03, p<0.05**	I^2=61.4%, p=0.000
			PM_{10}	20 studies. Per 10µg/m^3 increase in exposure: **OR 1.01, 95% CI 1.00-1.01**	I^2=56.1%, p=0.001
(Mustafić et al., 2012)	n=34 (12 time-series and 19 case-crossover); Europe, USA, Asia, Australia, South America (to November 2011)	Myocardial infarction, using ICD codes, clinical, laboratory, and/or angiographic criteria, or reported in myocardial registry	O_3	9 case-crossover, 10 time-series. Per 10µg/m^3 increase in exposure: RR 1.00, 95% CI 1.00-1.01, p=0.36	I^2=83.0%, p=0.560
			CO	11 case-crossover, 9 time-series. Per 1µg/m^3 increase in exposure: **OR 1.05, 95% CI 1.03-1.07, p<0.001**	I^2=93.0%, p=0.03
			NO_2	11 case-crossover, 10 time-series. Per 10µg/m^3 increase in exposure: RR 1.01, 95% CI 1.01-1.02, p<0.001	I^2=71.0%, p=0.08
			SO_2	6 case-crossover, 8 time-series. Per 10µg/m^3 increase in exposure: **RR 1.01, 95% CI 1.00-1.02, p=0.007**	I^2=65.0%, p=0.03
			$PM_{2.5}$	8 case-crossover, 5 time-series. Per 10µg/m^3 increase in exposure: **RR 1.03, 95% CI 1.02-1.04, p<0.001**	I^2=51.0%, p=0.004
			PM_{10}	7 case-crossover, 10 time-series. Per 10µg/m^3 increase in exposure: **RR 1.01, 95% CI 1.00-1.01, p=0.002**	I^2=57.0%, p=0.61
(Shah et al., 2013)	n=35 (11 case-crossover and 25 time-series); Europe, Canada, USA, Australasia, South America (to July 2012)	Heart failure, hospitalisation or mortality	CO	Per 10ppb increase in exposure: RR 0.46, 95% CI -0.10-1.02	I^2=87.0%, p=0.304
			NO_2	Per 1ppm increase in exposure: **RR 3.52, 95% CI 2.52-4.54**	I^2=91.0%, p<0.001
			SO_2	Per 10ppb increase in exposure: **RR 1.70, 95% CI 1.25-2.16**	I^2=91.0%, p=0.028
			$PM_{2.5}$	Per 10ppb increase in exposure: **RR 2.36, 95% CI 1.35-3.38**	I^2=78.0%, p=0.009
			PM_{10}	Per 10µg/m^3 increase in exposure: **RR 2.12, 95% CI 1.42-2.82**	I^2=53.0%, p=0.003
			PM_{10}	Per 10µg/m^3 increase in exposure: **RR 1.63, 95% CI 1.20-2.07**	I^2=75.0%, p=0.007
(Shah et al., 2015)	n=103 (34 case-crossover and 70 time-series); 28 countries (to July 2014)	Stroke, hospitalisation or mortality	O_3	Per 10ppb increase in exposure: RR 1.00, 95% CI 1.00-1.00	I^2=58.0%, p=0.014
			CO	Per 1ppm increase in exposure: **RR 1.02, 95% CI 1.00-1.03**	I^2=68.0%, p=0.070
			NO_2	Per 10ppb increase in exposure: **RR 1.01, 95% CI 1.01-1.02**	I^2=52.0%, p=0.036
			SO_2	Per 10ppb increase in exposure: **RR 1.02, 95% CI 1.01-1.03**	I^2=32.0%, p=0.098
			$PM_{2.5}$	Per 10µg/m^3 increase in exposure: **RR 1.01, 95% CI 1.01-1.01**	I^2=86.0%, p=0.670
			PM_{10}	Per 10µg/m^3 increase in exposure: **RR 1.00, 95% CI 1.00-1.00**	I^2=24.0%, p<0.001

*Statistically significant associations **bolded**

CI, confidence interval; CO, carbon monoxide; ICD, International Classification of Diseases; n, number of studies included; NO_x, nitrogen oxides; NO_2, nitrogen dioxide; OR, odds ratio; ppb, parts per billion; ppm, parts per million; O_3; ozone; RR, risk ratio; SO_2, sulphur dioxide; USA, United States of America; yr, years.

Table A12. Summary of *systematic reviews and random effects model meta-analyses* investigating associations between *lung cancer* and outdoor air pollution

Reference	n (study type); study locations (years included in review)	Lung cancer definition	Air pollutant	Studies included in meta-analysis. Estimate (RR, 95% CI)*	Meta-analysis statistics
(Hamra et al., 2014)	n=18 (17 cohort, 1 case-control); Europe, USA, Asia, New Zealand (to October 2013)	Lung cancer incidence and mortality	$PM_{2.5}$	13 cohort and 1 case-control. Per 10µg/m^3 increase in exposure: **RR 1.09, 95% CI 1.04-1.14**	I^2=53.0%, p=0.010
			PM_{10}	9 cohort. Per 10µg/m^3 increase in exposure: RR 1.08, 95% CI 1.00-1.17	I^2=74.6% p=0.000,
(Hamra et al., 2015)	n=20 (cohort); Europe, USA, Asia (to January 2014)	Lung cancer incidence and mortality	NO_2	15 cohort. Per 10µg/m^3 increase in exposure: **RR 1.04, 95% CI 1.01-1.09**	I^2=72.9%, p=0.000
			NO_x	5 cohort. Per 10µg/m^3 increase in exposure: **RR 1.03, 95% CI 1.01-1.05**	I^2=33.0%, p=0.202

*Statistically significant associations **bolded**

CI, confidence interval; n, number of studies included; NO_x, nitrogen oxides; NO_2, nitrogen dioxide; RR, risk ratio; USA, United States of America; yr, years.

Appendix B: Visual summary of urban characteristics that contribute to decreased non-communicable diseases risk factors and morbidity

Appendix C: Acronyms and abbreviations

Acronym or abbreviation	Definition
BMI	Body mass index
CHD	Coronary heart disease
CI	Confidence interval
CO	Carbon monoxide
COPD	Chronic obstructive pulmonary disorder
CVD	Cardiovascular disease
GIS	Geographical Information System
HbA1c	Glycated haemoglobin
HR	Hazard ratio
ICD	International Classification of Diseases
IRR	Incidence rate ratio
IQR	Inter-quartile range
MI	Myocardial infarction
MMR	Mortality rate ratio
n	Number of participants
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NZHS	New Zealand Health Survey
O_3	Ozone
OGTT	Oral glucose tolerance test
OR	Odds ratio
$PM_{2.5}$	Particulate matter, diameter <2.5µm
PM_{10}	Particulate matter, diameter <10µm
ppb	Parts per billion
ppm	Parts per million
PR	Prevalence ratio
SD	Standard deviation
SES	Socioeconomic status
SO_2	Sulphur dioxide
RR	Risk ratio / relative risk
T2DM	Type 2 diabetes mellitus
UK	United Kingdom
USA	United States of America

References

Adams, M. A., Frank, L. D., Schipperijn, J., Smith, G., Chapman, J., Christiansen, L. B., Coffee, N., Salvo, D., du Toit, L., Dygrýn, J., et al. (2014). International variation in neighborhood walkability, transit, and recreation environments using geographic information systems: the IPEN adult study. *International Journal of Health Geographics, 13*, 43.

Alcock, I., White, M. P., Wheeler, B. W., Fleming, L. E., & Depledge, M. H. (2014). Longitudinal effects on mental health of moving to greener and less green urban areas. *Environmental Science & Technology, 48*(2), 1247-1255.

Alegría, M., Molina, K. M., & Chen, C. N. (2014). Neighborhood characteristics and differential risk for depressive and anxiety disorders across racial/ethnic groups in the United States. *Depression and Anxiety, 31*(1), 27-37.

Annerstedt, M., Östergren, P.-O., Björk, J., Grahn, P., Skärbäck, E., & Währborg, P. (2012). Green qualities in the neighbourhood and mental health - results from a longitudinal cohort study in Southern Sweden. *BMC Public Health, 12*, 337.

Astell-Burt, T., Feng, X., & Kolt, G. S. (2013). Mental health benefits of neighbourhood green space are stronger among physically active adults in middle-to-older age: evidence from 260,061 Australians. *Preventive Medicine, 57*(5), 601-606.

Astell-Burt, T., Feng, X., & Kolt, G. S. (2014a). Is neighborhood green space associated with a lower risk of type 2 diabetes? Evidence from 267,072 Australians. *Diabetes Care, 37*(1), 197-201.

Astell-Burt, T., Feng, X., & Kolt, G. S. (2014b). Neighbourhood green space and the odds of having skin cancer: multilevel evidence of survey data from 267 072 Australians. *Journal of Epidemiology and Community Health, 68*(4), 370-374.

Astell-Burt, T., Mitchell, R., & Hartig, T. (2014c). The association between green space and mental health varies across the lifecourse. A longitudinal study. *Journal of Epidemiology and Community Health, 68*(6), 578-583.

Atkinson, J., Salmond, C., & Crampton, P. (2014). NZDep2013 Index of Deprivation. Wellington, NZ: Department of Public Health, University of Otago. Retrieved from www.otago.ac.nz/wellington/otago069936.pdf

Ayuka, F., Barnett, R., & Pearce, J. (2014). Neighbourhood availability of alcohol outlets and hazardous alcohol consumption in New Zealand. *Health & Place, 29*, 186-199.

Ayuka Owuor, C. F. (2010). *Examining place influence on alcohol related behaviour and health outcomes in New Zealand. A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Geography.* University of Canterbury, Christchurch, NZ. Retrieved from http://hdl.handle.net/10092/5346

Backholer, K., Beauchamp, A., Ball, K., Turrell, G., Martin, J., Woods, J., & Peeters, A. (2014). A framework for evaluating the impact of obesity prevention strategies on socioeconomic inequalities in weight. *American Journal of Public Health, 104*(10), e43-50.

Badland, H. M., Keam, R., Witten, K., & Kearns, R. (2010). Examining public open spaces by neighborhood-level walkability and deprivation. *Journal of Physical Activity & Health, 7*(6), 818-824.

Badland, H. M., Schofield, G. M., Witten, K., Schluter, P. J., Mavoa, S., Kearns, R. A., Hinckson, E. A., Oliver, M., Kaiwai, H., Jensen, V. G., et al. (2009). Understanding the Relationship between Activity and Neighbourhoods (URBAN) Study: research design and methodology. *BMC Public Health, 9*, 224.

Balti, E. V., Echouffo-Tcheugui, J. B., Yako, Y. Y., & Kengne, A. P. (2014). Air pollution and risk of type 2 diabetes mellitus: a systematic review and meta-analysis. *Diabetes Research and Clinical Practice, 106*(2), 161-172.

Barton, H., & Grant, M. (2006). A health map for the local human habitat. *The Journal for the Royal Society for the Promotion of Health, 126*(6), 252-253.

Bauer, S. E., Wagner, S. E., Burch, J., Bayakly, R., & Vena, J. E. (2013). A case-referent study: light at night and breast cancer risk in Georgia. *International Journal of Health Geographics, 12*, 23.

Beauchamp, A., Backholer, K., Magliano, D., & Peeters, A. (2014). The effect of obesity prevention interventions according to socioeconomic position: a systematic review. *Obesity Reviews, 15*(7), 541-554.

Bluhm, G., & Eriksson, C. (2011). Cardiovascular effects of environmental noise: research in Sweden. *Noise & Health, 13*(52), 212-216.

Bodicoat, D. H., O'Donovan, G., Dalton, A. M., Gray, L. J., Yates, T., Edwardson, C., Hill, S., Webb, D. R., Khunti, K., Davies, M. J., et al. (2014). The association between neighbourhood greenspace and type 2 diabetes in a large cross-sectional study. *BMJ Open, 4*(12), e006076.

Booth, G. L., Creatore, M. I., Moineddin, R., Gozdyra, P., Weyman, J. T., Matheson, F. I., & Glazier, R. H. (2013). Unwalkable neighborhoods, poverty, and the risk of diabetes among recent immigrants to Canada compared with long-term residents. *Diabetes Care, 36*(2), 302-308.

Bowie, C., Beere, P., Griffin, E., Campbell, M., & Kingham, S. (2013). Variation in health and social equity in the spaces where we live: a review of previous literature from the GeoHealth Laboratory. *New Zealand Sociology, 28*(3), 164.

Brennan, S. L., & Turrell, G. (2012). Neighborhood disadvantage, individual-level socioeconomic position, and self-reported chronic arthritis: a cross-sectional multilevel study. *Arthritis Care and Research, 64*(5), 721-728.

Bryden, A., Roberts, B., McKee, M., & Petticrew, M. (2012). A systematic review of the influence on alcohol use of community level availability and marketing of alcohol. *Health & Place, 18*(2), 349-357.

Bryden, A., Roberts, B., Petticrew, M., & McKee, M. (2013). A systematic review of the influence of community level social factors on alcohol use. *Health & Place, 21*, 70-85.

California Center for Public Health Advocacy. (2008a). Designed for disease: the link between local food environments and obesity and diabetes. Los Angeles: PolicyLink, UCLA Center for Health Policy Research. Retrieved from www.publichealthadvocacy.org/PDFs/RFEI%20Policy%20Brief_finalweb.pdf

California Center for Public Health Advocacy. (2008b). Designed for disease: the link between local food environments and obesity and diabetes: detailed methodology. Los Angeles: PolicyLink, UCLA Center for Health Policy Research. Retrieved from http://healthpolicy.ucla.edu/publications/Documents/PDF/Designed%20for%20Disease%20The%20Link%20Between%20Local%20Food%20Environments%20and%20Obesity%20and%20Diabetes%203.pdf

Casciano, R., & Massey, D. S. (2012). Neighborhood disorder and anxiety symptoms: new evidence from a quasi-experimental study. *Health & Place, 18*(2), 180-190.

Centers for Disease Control and Prevention. (2016). Arthritis. from http://www.cdc.gov/arthritis/index.htm

Cesaroni, G., Forastiere, F., Stafoggia, M., Andersen, Z. J., Badaloni, C., Beelen, R., Caracciolo, B., de Faire, U., Erbel, R., Eriksen, K. T., et al. (2014). Long term exposure to ambient air pollution and incidence of acute coronary events: prospective cohort study and meta-analysis in 11 European cohorts from the ESCAPE Project. *BMJ, 348*, f7412.

Chan, W. C., Wright, C., Riddell, T., Wells, S., Kerr, A. J., Gala, G., & Jackson, R. (2008). Ethnic and socioeconomic disparities in the prevalence of cardiovascular disease in New Zealand. *New Zealand Medical Journal, 121*(1285), 11-20.

Chong, S., Lobb, E., Khan, R., Abu-Rayya, H., Byun, R., & Jalaludin, B. (2013). Neighbourhood safety and area deprivation modify the associations between parkland and psychological distress in Sydney, Australia. *BMC Public Health, 13*, 422.

Christchurch City Council. (undated). Health promotion and sustainability through environmental design: a guide for planning. Christchurch, NZ: CCC. Retrieved from http://resources.ccc.govt.nz/files/HPSTED.pdf

Christian, H., Knuiman, M., Bull, F., Timperio, A., Foster, S., Divitini, M., Middleton, N., & Giles-Corti, B. (2013). A new urban planning code's impact on walking: the residential environments project. *American Journal of Public Health, 103*(7), 1219-1228.

Christian, H., Zubrick, S. R., Foster, S., Giles-Corti, B., Bull, F., Wood, L., Knuiman, M., Brinkman, S., Houghton, S., & Boruff, B. (2015). The influence of the neighborhood physical environment on early child health and development: a review and call for research. *Health & Place, 33*, 25-36.

Christine, P. J., Auchincloss, A. H., Bertoni, A. G., Carnethon, M. R., Sánchez, B. N., Moore, K., Adar, S. D., Horwich, T. B., Watson, K. E., & Diez Roux, A. V. (2015). Longitudinal associations between neighborhood physical and social environments and incident type 2 diabetes mellitus: the Multi-Ethnic Study of Atherosclerosis (MESA). *JAMA Internal Medicine, 175*(8), 1311-1320.

Cobb, L. K., Appel, L. J., Franco, M., Jones-Smith, J. C., Nur, A., & Anderson, C. A. (2015). The relationship of the local food environment with obesity: a systematic review of methods, study quality, and results. *Obesity, 23*(7), 1331-1344.

Coffee, N. T., Howard, N., Paquet, C., Hugo, G., & Daniel, M. (2013). Is walkability associated with a lower cardiometabolic risk? *Health & Place, 21*, 163-169.

Coggon, D., Rose, G., & Barker, D. J. P. (2003). Epidemiology for the uninitiated (4th ed.): BMJ. Retrieved from www.bmj.com/about-bmj/resources-readers/publications/epidemiology-uninitiated

Cohen-Cline, H., Turkheimer, E., & Duncan, G. E. (2015). Access to green space, physical activity and mental health: a twin study. *Journal of Epidemiology and Community Health, 69*(6), 523-529.

Commission on Social Determinants of Health. (2008). Closing the gap in a generation: health equity through action on the social determinants of health. Final Report of the Commission on Social Determinants of Health Geneva, Switzerland: World Health Organization. Retrieved from www.who.int/social_determinants/final_report/csdh_finalreport_2008.pdf

Connor, J. L., Kypri, K., Bell, M. L., & Cousins, K. (2011). Alcohol outlet density, levels of drinking and alcohol-related harm in New Zealand: a national study. *Journal of Epidemiology and Community Health, 65*(10), 841-846.

Cooper-Vince, C. E., Chan, P. T., Pincus, D. B., & Comer, J. S. (2014). Paternal autonomy restriction, neighborhood safety, and child anxiety trajectory in community youth. *Journal of Applied Developmental Psychology, 35*(4), 265-272.

Cooper, R., Boyko, C. T., & Cooper, C. (2011). Design for health: the relationship between design and noncommunicable diseases. *Journal of Health Communication, 16*(Suppl 2), 134-157.

Coulon, S. M., Wilson, D. K., & Egan, B. M. (2013). Associations among environmental supports, physical activity, and blood pressure in African-American adults in the PATH trial. *Social Science and Medicine, 87*, 108-115.

Craig, P., Cooper, C., Gunnell, D., Haw, S., Lawson, K., Macintyre, S., Ogilvie, D., Petticrew, M., Reeves, B., Sutton, M., et al. (2011). Using natural experiments to evaluate population health interventions: guidance for producers and users of evidence. London, UK: Medical Research Council. Retrieved from www.mrc.ac.uk/documents/pdf/natural-experiments-guidance/

Craig, P., Cooper, C., Gunnell, D., Haw, S., Lawson, K., Macintyre, S., Ogilvie, D., Petticrew, M., Reeves, B., Sutton, M., et al. (2012). Using natural experiments to evaluate population health interventions: new Medical Research Council guidance. *Journal of Epidemiology and Community Health, 66*(12), 1182-1186.

Creatore, M. I., Glazier, R. H., Moineddin, R., Fazli, G. S., Johns, A., Gozdyra, P., Matheson, F. I., Kaufman-Shriqui, V., Rosella, L. C., Manuel, D. G., et al. (2016). Association of neighborhood walkability with change in overweight, obesity, and diabetes. *JAMA, 315*(20), 2211-2220.

Day, P. L., & Pearce, J. (2011). Obesity-promoting food environments and the spatial clustering of food outlets around schools. *American Journal of Preventive Medicine, 40*(2), 113-121.

Day, P. L., Pearce, J. R., & Pearson, A. L. (2015). A temporal analysis of the spatial clustering of food outlets around schools in Christchurch, New Zealand, 1966 to 2006. *Public Health Nutrition, 18*(1), 135-142.

De Bourdeaudhuij, I., Van Dyck, D., Salvo, D., Davey, R., Reis, R. S., Schofield, G., Sarmiento, O. L., Mitas, J., Christiansen, L. B., MacFarlane, D., et al. (2015). International study of perceived neighbourhood environmental attributes and Body Mass Index: IPEN Adult study in 12 countries. *International Journal of Behavioral Nutrition and Physical Activity, 12*, 62.

de Vet, E., de Ridder, D. T., & de Wit, J. B. (2011). Environmental correlates of physical activity and dietary behaviours among young people: a systematic review of reviews. *Obesity Reviews, 12*(5), e130-142.

Diez Roux, A. V. (2007). Neighborhoods and health: where are we and were do we go from here? *Revue d'Épidémiologie et de Santé Publique, 55*(1), 13-21.

Diez Roux, A. V. (2016). Neighborhoods and health: what do we know? What should we do? *American Journal of Public Health, 106*(3), 430-431.

Diez Roux, A. V., & Mair, C. (2010). Neighborhoods and health. *Annals of the New York Academy of Sciences, 1186*, 125-145.

Ding, D., Adams, M. A., Sallis, J. F., Norman, G. J., Hovell, M. F., Chambers, C. D., Hofstetter, C. R., Bowles, H. R., Hagströmer, M., Craig, C. L., et al. (2013). Perceived neighborhood environment and physical activity in 11 countries: do associations differ by country? *International Journal of Behavioral Nutrition and Physical Activity, 10*, 57.

Ding, D., Sallis, J. F., Kerr, J., Lee, S., & Rosenberg, D. E. (2011). Neighborhood environment and physical activity among youth: a review. *American Journal of Preventive Medicine, 41*(4), 442-455.

Dubowitz, T., Ghosh-Dastidar, M., Eibner, C., Slaughter, M. E., Fernandes, M., Whitsel, E. A., Bird, C. E., Jewell, A., Margolis, K. L., Li, W., et al. (2012). The Women's Health Initiative: the food environment, neighborhood socioeconomic status, BMI, and blood pressure. *Obesity, 20*(4), 862-871.

Durand, C. P., Andalib, M., Dunton, G. F., Wolch, J., & Pentz, M. A. (2011). A systematic review of built environment factors related to physical activity and obesity risk: implications for smart growth urban planning. *Obesity Reviews, 12*(5), e173-182.

Exeter, D. J., Sabel, C. E., Hanham, G., Lee, A. C., & Wells, S. (2015). Movers and stayers: the geography of residential mobility and CVD hospitalisations in Auckland, New Zealand. *Social Science and Medicine, 133*, 331-339.

Eze, I. C., Hemkens, L. G., Bucher, H. C., Hoffmann, B., Schindler, C., Künzli, N., Schikowski, T., & Probst-Hensch, N. M. (2015). Association between ambient air pollution and diabetes mellitus in Europe and North America: systematic review and meta-analysis. *Environmental Health Perspectives, 123*(5), 381-389.

Feng, J., Glass, T. A., Curriero, F. C., Stewart, W. F., & Schwartz, B. S. (2010). The built environment and obesity: a systematic review of the epidemiologic evidence. *Health & Place, 16*(2), 175-190.

Ferdinand, A. O., Sen, B., Rahurkar, S., Engler, S., & Menachemi, N. (2012). The relationship between built environments and physical activity: a systematic review. *American Journal of Public Health, 102*(10), e7-e13.

Field, A., Witten, K., Robinson, E., & Pledger, M. (2004). Who gets to what? Access to community resources in two New Zealand cities. *Urban Policy and Research, 22*(2), 189-205.

Fisher, E., & Griffin, K. (2016). Interventions for healthy eating and active urban living: a guide for improving community health: The New York Academy of Medicine, DASH NYC. Retrieved from www.nyam.org/publications/publication/interventions-healthy-eating-and-active-urban-living-guide-improving-community-health/

Fleischhacker, S. E., Evenson, K. R., Rodriguez, D. A., & Ammerman, A. S. (2011). A systematic review of fast food access studies. *Obesity Reviews, 12*(5), e460-471.

Foster, S., Hooper, P., Knuiman, M., Bull, F., & Giles-Corti, B. (2015). Are liveable neighbourhoods safer neighbourhoods? Testing the rhetoric on new urbanism and safety from crime in Perth, Western Australia. *Social Science and Medicine, In press*.

Francis, J., Wood, L. J., Knuiman, M., & Giles-Corti, B. (2012). Quality or quantity? Exploring the relationship between Public Open Space attributes and mental health in Perth, Western Australia. *Social Science and Medicine, 74*(10), 1570-1577.

Freedman, V. A., Grafova, I. B., & Rogowski, J. (2011). Neighborhoods and chronic disease onset in later life. *American Journal of Public Health, 101*(1), 79-86.

Fuks, K., Moebus, S., Hertel, S., Viehmann, A., Nonnemacher, M., Dragano, N., Möhlenkamp, S., Jakobs, H., Kessler, C., Erbel, R., et al. (2011). Long-term urban particulate air pollution, traffic noise, and arterial blood pressure. *Environmental Health Perspectives, 119*(12), 1706-1711.

Furr-Holden, C. D., Milam, A. J., Young, K. C., Macpherson, L., & Lejuez, C. W. (2011). Exposure to hazardous neighborhood environments in late childhood and anxiety. *Journal of Community Psychology, 39*(7), 876-883.

Galvez, M. P., Pearl, M., & Yen, I. H. (2010). Childhood obesity and the built environment. *Current Opinion in Pediatrics, 22*(2), 202-207.

Gamba, R. J., Schuchter, J., Rutt, C., & Seto, E. Y. (2015). Measuring the food environment and its effects on obesity in the United States: a systematic review of methods and results. *Journal of Community Health, 40*(3), 464-475.

Gariépy, G., Blair, A., Kestens, Y., & Schmitz, N. (2014). Neighbourhood characteristics and 10-year risk of depression in Canadian adults with and without a chronic illness. *Health & Place, 30*, 279-286.

Gariépy, G., Kaufman, J. S., Blair, A., Kestens, Y., & Schmitz, N. (2015a). Place and health in diabetes: the neighbourhood environment and risk of depression in adults with type 2 diabetes. *Diabetic Medicine, 32*(7), 944-950.

Gariépy, G., Thombs, B. D., Kestens, Y., Kaufman, J. S., Blair, A., & Schmitz, N. (2015b). The neighbourhood built environment and trajectories of depression symptom episodes in adults: a latent class growth analysis. *PloS One, 10*(7), e0133603.

Garrett, N., Schluter, P. J., & Schofield, G. (2012). Physical activity profiles and perceived environmental determinants in New Zealand: a national cross-sectional study. *Journal of Physical Activity & Health, 9*(3), 367-377.

Giles-Corti, B., Foster, S., Shilton, T., & Falconer, R. (2010). The co-benefits for health of investing in active transportation. *NSW Public Health Bulletin, 21*(5-6), 122-127.

Giles-Corti, B., Hooper, P., Foster, S., Koohsari, M. J., & Francis, J. (2014). Low density development: impacts on physical activity and associated health outcomes. Evidence review: National Heart Foundation of Australia. Retrieved from www.heartfoundation.org.au/images/uploads/publications/FINAL_Heart_Foundation_Low_density_Report_September_2014.pdf

Giles-Corti, B., Knuiman, M., Timperio, A., Van Niel, K., Pikora, T. J., Bull, F. C., Shilton, T., & Bulsara, M. (2008). Evaluation of the implementation of a state government community design policy aimed at increasing local walking: design issues and baseline results from RESIDE, Perth Western Australia. *Preventive Medicine, 46*(1), 46-54.

Giles-Corti, B., Sallis, J. F., Sugiyama, T., Frank, L. D., Lowe, M., & Owen, N. (2015). Translating active living research into policy and practice: one important pathway to chronic disease prevention. *Journal of Public Health Policy, 36*(2), 231-243.

Giorgini, P., Di Giosia, P., Grassi, D., Rubenfire, M., Brook, R. D., & Ferri, C. (2016). Air pollution exposure and blood pressure: an updated review of the literature. *Current Pharmaceutical Design, 22*(1), 28-51.

Giskes, K., van Lenthe, F., Avendano-Pabon, M., & Brug, J. (2011). A systematic review of environmental factors and obesogenic dietary intakes among adults: are we getting closer to understanding obesogenic environments? *Obesity Reviews, 12*(5), e95-e106.

Gmel, G., Holmes, J., & Studer, J. (2016). Are alcohol outlet densities strongly associated with alcohol-related outcomes? A critical review of recent evidence. *Drug and Alcohol Review, 35*(1), 40-54.

Gomez, S. L., Shariff-Marco, S., DeRouen, M., Keegan, T. H., Yen, I. H., Mujahid, M., Satariano, W. A., & Glaser, S. L. (2015). The impact of neighborhood social and built environment factors across the cancer continuum: current research, methodological considerations, and future directions. *Cancer, 121*(14), 2314-2330.

Goodman, A., Sahlqvist, S., Ogilvie, D., & on behalf of the iConnect Consortium. (2013). Who uses new walking and cycling infrastructure and how? Longitudinal results from the UK iConnect study. *Preventive Medicine, 57*(5), 518-524.

Goodman, A., Sahlqvist, S., Ogilvie, D., & on behalf of the iConnect Consortium. (2014). New walking and cycling routes and increased physical activity: one- and 2-year findings from the UK iConnect Study. *American Journal of Public Health, 104*(9), e38-46.

Gordon-Larsen, P. (2014). Food availability/convenience and obesity. *Advances in Nutrition, 5*(6), 809-817.

Grasser, G., Van Dyck, D., Titze, S., & Stronegger, W. (2013). Objectively measured walkability and active transport and weight-related outcomes in adults: a systematic review. *International Journal of Public Health, 58*(4), 615-625.

Griffin, B. A., Eibner, C., Bird, C. E., Jewell, A., Margolis, K., Shih, R., Ellen Slaughter, M., Whitsel, E. A., Allison, M., & Escarce, J. J. (2013). The relationship between urban sprawl and coronary heart disease in women. *Health & Place, 20*, 51-61.

Hamra, G. B., Guha, N., Cohen, A., Laden, F., Raaschou-Nielsen, O., Samet, J. M., Vineis, P., Forastiere, F., Saldiva, P., Yorifuji, T., et al. (2014). Outdoor particulate matter exposure and lung cancer: a systematic review and meta-analysis. *Environmental Health Perspectives, 122*(9), 906-911.

Hamra, G. B., Laden, F., Cohen, A. J., Raaschou-Nielsen, O., Brauer, M., & Loomis, D. (2015). Lung cancer and exposure to nitrogen dioxide and traffic: a systematic review and meta-analysis. *Environmental Health Perspectives, 123*(11), 1107-1112.

Hansel, N. N., McCormack, M. C., & Kim, V. (2016). The effects of air pollution and temperature on COPD. *COPD: Journal of Chronic Obstructive Pulmonary Disease, 13*(3), 372-379.

Haselwandter, E. M., Corcoran, M. P., Folta, S. C., Hyatt, R., Fenton, M., & Nelson, M. E. (2015). The built environment, physical activity, and aging in the United States: a state of the science review. *Journal of Aging and Physical Activity, 23*(2), 323-329.

Hay, G. C., Whigham, P. A., Kypri, K., & Langley, J. D. (2009). Neighbourhood deprivation and access to alcohol outlets: a national study. *Health & Place, 15*(4), 1086-1093.

Haynes, R., Pearce, J., & Barnett, R. (2008). Cancer survival in New Zealand: ethnic, social and geographical inequalities. *Social Science and Medicine, 67*(6), 928-937.

Hirsch, J. A., Diez Roux, A. V., Moore, K. A., Evenson, K. R., & Rodriguez, D. A. (2014). Change in walking and body mass index following residential relocation: the Multi-Ethnic Study of Atherosclerosis. *American Journal of Public Health, 104*(3), e49-56.

Hooper, P., Giles-Corti, B., & Knuiman, M. (2014). Evaluating the implementation and active living impacts of a state government planning policy designed to create walkable neighborhoods in Perth, Western Australia. *American Journal of Health Promotion, 28*(Suppl 3), S5-18.

Hooper, P., Knuiman, M., Bull, F., Jones, E., & Giles-Corti, B. (2015a). Are we developing walkable suburbs through urban planning policy? Identifying the mix of design requirements to optimise walking outcomes from the 'Liveable Neighbourhoods' planning policy in Perth, Western Australia. *International Journal of Behavioral Nutrition and Physical Activity, 12*, 63.

Hooper, P., Knuiman, M., Foster, S., & Giles-Corti, B. (2015b). The building blocks of a 'Liveable Neighbourhood': identifying the key performance indicators for walking of an operational planning policy in Perth, Western Australia. *Health & Place, 36*, 173-183.

Howden-Chapman, P., Keall, M., Conlon, F., & Chapman, R. (2015). Urban interventions: understanding health co-benefits. *Urban Design and Planning, 168*(DP4), 196-203.

Huckle, T., Huakau, J., Sweetsur, P., Huisman, O., & Casswell, S. (2008). Density of alcohol outlets and teenage drinking: living in an alcogenic environment is associated with higher consumption in a metropolitan setting. *Addiction, 103*(10), 1614-1621.

Hunter, R. F., Christian, H., Veitch, J., Astell-Burt, T., Hipp, J. A., & Schipperijn, J. (2015). The impact of interventions to promote physical activity in urban green space: a systematic review and recommendations for future research. *Social Science and Medicine, 124*, 246-256.

Hurley, S., Goldberg, D., Nelson, D., Hertz, A., Horn-Ross, P. L., Bernstein, L., & Reynolds, P. (2014). Light at night and breast cancer risk among California teachers. *Epidemiology, 25*(5), 697-706.

Ivory, V. C., Blakely, T., Pearce, J., Witten, K., Bagheri, N., Badland, H., & Schofield, G. (2015a). Could strength of exposure to the residential neighbourhood modify associations between walkability and physical activity? *Social Science and Medicine, 147*, 232-241.

Ivory, V. C., Russell, M., Witten, K., Hooper, C. M., Pearce, J., & Blakely, T. (2015b). What shape is your neighbourhood? Investigating the micro geographies of physical activity. *Social Science and Medicine, 133*, 313-321.

Jackson, N., Denny, S., & Ameratunga, S. (2014). Social and socio-demographic neighborhood effects on adolescent alcohol use: a systematic review of multi-level studies. *Social Science and Medicine, 115*, 10-20.

Janghorbani, M., Momeni, F., & Mansourian, M. (2014). Systematic review and metaanalysis of air pollution exposure and risk of diabetes. *European Journal of Epidemiology, 29*(4), 231-242.

Jones-Rounds, M. L., Evans, G. W., & Braubach, M. (2014). The interactive effects of housing and neighbourhood quality on psychological well-being. *Journal of Epidemiology and Community Health, 68*(2), 171-175.

Jordan, K. P., Hayward, R., Roberts, E., Edwards, J. J., & Kadam, U. T. (2014). The relationship of individual and neighbourhood deprivation with morbidity in older adults: an observational study. *European Journal of Public Health, 24*(3), 396-398.

Joshy, G., Porter, T., Le Lievre, C., Lane, J., Williams, M., & Lawrenson, R. (2009). Prevalence of diabetes in New Zealand general practice: the influence of ethnicity and social deprivation. *Journal of Epidemiology and Community Health, 63*(5), 386-390.

Kamimura, A., Christensen, N., Tabler, J., Prevedel, J. A., Ojha, U., Solis, S. P., Hamilton, B. J., Ashby, J., & Reel, J. J. (2014). Depression, somatic symptoms, and perceived neighborhood environments among US-born and non-US-born free clinic patients. *Southern Medical Journal, 107*(9), 591-596.

Karriker-Jaffe, K. J. (2011). Areas of disadvantage: a systematic review of effects of area-level socioeconomic status on substance use outcomes. *Drug and Alcohol Review, 30*(1), 84-95.

Kawakami, N., Li, X., & Sundquist, K. (2011). Health-promoting and health-damaging neighbourhood resources and coronary heart disease: a follow-up study of 2 165 000 people. *Journal of Epidemiology and Community Health, 65*(10), 866-872.

Keall, M., Chapman, R., Howden-Chapman, P., Witten, K., Abrahamse, W., & Woodward, A. (2015). Increasing active travel: results of a quasi-experimental study of an intervention to encourage walking and cycling. *Journal of Epidemiology and Community Health, 69*(12), 1184-1190.

Kent, J., Thompson, S. M., & Jalaludin, B. (2011). Healthy built environments: a review of the literature. Sydney, Australia: The Healthy Built Environments Program, City Futures Research Centre, The University of New South Wales. Retrieved from www.be.unsw.edu.au/sites/default/files/upload/pdf/cf/hbep/publications/attachments/HBEPLiteratureReview_FullDocument.pdf

Kershaw, K. N., Diez Roux, A. V., Bertoni, A., Carnethon, M. R., Everson-Rose, S. A., & Liu, K. (2015). Associations of chronic individual-level and neighbourhood-level stressors with incident coronary heart disease: the Multi-Ethnic Study of Atherosclerosis. *Journal of Epidemiology and Community Health, 69*(2), 136-141.

Koohsari, M. J., Mavoa, S., Villanueva, K., Sugiyama, T., Badland, H., Kaczynski, A. T., Owen, N., & Giles-Corti, B. (2015). Public open space, physical activity, urban design and public health: concepts, methods and research agenda. *Health & Place, 33*, 75-82.

Lachowycz, K., & Jones, A. P. (2011). Greenspace and obesity: a systematic review of the evidence. *Obesity Reviews, 12*(5), e183-189.

Leal, C., & Chaix, B. (2011). The influence of geographic life environments on cardiometabolic risk factors: a systematic review, a methodological assessment and a research agenda. *Obesity Reviews, 12*(3), 217-230.

Lee, A. C. K., & Maheswaran, R. (2011). The health benefits of urban green spaces: a review of the evidence. *Journal of Public Health, 33*(2), 212-222.

Lee, R. E., Mama, S. K., & Adamus-Leach, H. J. (2012). Neighborhood street scale elements, sedentary time and cardiometabolic risk factors in inactive ethnic minority women. *PloS One, 7*(12), e51081.

Lin, E. Y., Witten, K., Casswell, S., & You, R. Q. (2012). Neighbourhood matters: perceptions of neighbourhood cohesiveness and associations with alcohol, cannabis and tobacco use. *Drug and Alcohol Review, 31*(4), 402-412.

Lipperman-Kreda, S., Grube, J. W., & Friend, K. B. (2012). Local tobacco policy and tobacco outlet density: associations with youth smoking. *Journal of Adolescent Health, 50*(6), 547-552.

Lipperman-Kreda, S., Grube, J. W., Friend, K. B., & Mair, C. (2016). Tobacco outlet density, retailer cigarette sales without ID checks and enforcement of underage tobacco laws: associations with youths' cigarette smoking and beliefs. *Addiction, 111*(3), 525-532.

Lipperman-Kreda, S., Mair, C., Grube, J. W., Friend, K. B., Jackson, P., & Watson, D. (2014). Density and proximity of tobacco outlets to homes and schools: relations with youth cigarette smoking. *Prevention Science, 15*(5), 738-744.

London Healthy Urban Development Unit. (2015). Healthy urban planning checklist (2nd ed.). London, UK: NHS. Retrieved from http://www.healthyurbandevelopment.nhs.uk/wp-content/uploads/2015/07/Healthy-Urban-Planning-Checklist-June-2015.pdf

Lorenc, T., Petticrew, M., Welch, V., & Tugwell, P. (2013). What types of interventions generate inequalities? Evidence from systematic reviews. *Journal of Epidemiology and Community Health, 67*(2), 190-193.

Lowe, M., Boulange, C., & Giles-Corti, B. (2014). Urban design and health: progress to date and future challenges. *Health Promotion Journal of Australia, 25*(1), 14-18.

Lucan, S. C. (2015). Concerning limitations of food-environment research: a narrative review and commentary framed around obesity and diet-related diseases in youth. *Journal of the Academy of Nutrition and Dietetics, 115*(2), 205-212.

Ludwig, J., Sanbonmatsu, L., Gennetian, L., Adam, E., Duncan, G. J., Katz, L. F., Kessler, R. C., Kling, J. R., Lindau, S. T., Whitaker, R. C., et al. (2011). Neighborhoods, obesity, and diabetes -a randomized social experiment. *New England Journal of Medicine, 365*(16), 1509-1519.

Luo, C., Zhu, X., Yao, C., Hou, L., Zhang, J., Cao, J., & Wang, A. (2015). Short-term exposure to particulate air pollution and risk of myocardial infarction: a systematic review and meta-analysis. *Environmental Science and Pollution Research International, 22*(19), 14651-14662.

Maas, J., Verheij, R. A., de Vries, S., Spreeuwenberg, P., Schellevis, F. G., & Groenewegen, P. P. (2009). Morbidity is related to a green living environment. *Journal of Epidemiology and Community Health, 63*(12), 967-973.

MacDonald, J. M., Stokes, R. J., Cohen, D. A., Kofner, A., & Ridgeway, G. K. (2010). The effect of light rail transit on body mass index and physical activity. *American Journal of Preventive Medicine, 39*(2), 105-112.

Mackenbach, J. D., Rutter, H., Compernolle, S., Glonti, K., Oppert, J.-M., Charreire, H., De Bourdeaudhuij, I., Brug, J., Nijpels, G., & Lakerveld, J. (2014). Obesogenic environments: a systematic review of the association between the physical environment and adult weight status, the SPOTLIGHT project. *BMC Public Health, 14*, 233.

Macmillan, A., Connor, J., Witten, K., Kearns, R., Rees, D., & Woodward, A. (2014). The societal costs and benefits of commuter bicycling: simulating the effects of specific policies using system dynamics modeling. *Environmental Health Perspectives, 122*(4), 335-344.

Mann, C. J. (2003). Observational research methods. Research design II: cohort, cross sectional, and case-control studies. *Emergency Medicine Journal, 20*(1), 54-60.

Marashi-Pour, S., Cretikos, M., Lyons, C., Rose, N., Jalaludin, B., & Smith, J. (2015). The association between the density of retail tobacco outlets, individual smoking status, neighbourhood socioeconomic status and school locations in New South Wales, Australia. *Spat Spatiotemporal Epidemiol, 12*, 1-7.

Marmot, M., Friel, S., Bell, R., Houweling, T. A., Taylor, S., & on behalf of the Commission on Social Determinants of Health. (2008). Closing the gap in a generation: health equity through action on the social determinants of health. *Lancet, 372*(9650), 1661-1669.

Marsh, L., Ajmal, A., McGee, R., Robertson, L., Cameron, C., & Doscher, C. (2015). Tobacco retail outlet density and risk of youth smoking in New Zealand. *Tobacco Control, In press*.

Marsh, L., Doscher, C., & Robertson, L. A. (2013). Characteristics of tobacco retailers in New Zealand. *Health & Place, 23*, 165-170.

Martinelli, N., Olivieri, O., & Girelli, D. (2013). Air particulate matter and cardiovascular disease: a narrative review. *European Journal of Internal Medicine, 24*(4), 295-302.

Mayne, S. L., Auchincloss, A. H., & Michael, Y. L. (2015). Impact of policy and built environment changes on obesity-related outcomes: a systematic review of naturally occurring experiments. *Obesity Reviews, 16*(5), 362-375.

McCormack, G. R., & Shiell, A. (2011). In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. *International Journal of Behavioral Nutrition and Physical Activity, 8*, 125.

McCrorie, P. R., Fenton, C., & Ellaway, A. (2014). Combining GPS, GIS, and accelerometry to explore the physical activity and environment relationship in children and young people - a review. *International Journal of Behavioral Nutrition and Physical Activity, 11*, 93.

McFadden, K., McConnell, D., Salmond, C., Crampton, P., & Fraser, J. (2004). Socioeconomic deprivation and the incidence of cervical cancer in New Zealand: 1988-1998. *New Zealand Medical Journal, 117*(1206), U1172.

McGrath, L. J., Hinckson, E. A., Hopkins, W. G., Mavoa, S., Witten, K., & Schofield, G. (2016). Associations between the neighborhood environment and moderate-to-vigorous walking in New Zealand children: findings from the URBAN Study. *Sports Medicine, 46*(7), 1003-1017.

McGrath, L. J., Hopkins, W. G., & Hinckson, E. A. (2015). Associations of objectively measured built-environment attributes with youth moderate-vigorous physical activity: a systematic review and meta-analysis. *Sports Medicine, 45*(6), 841-865.

McKenzie, F., Ellison-Loschmann, L., & Jeffreys, M. (2010). Investigating reasons for socioeconomic inequalities in breast cancer survival in New Zealand. *Cancer Epidemiology, 34*(6), 702-708.

Miles, R., Coutts, C., & Mohamadi, A. (2012). Neighborhood urban form, social environment, and depression. *Journal of Urban Health, 89*(1), 1-18.

Ministry for the Environment. (2005). New Zealand urban design protocol. Wellington, NZ: MfE. Retrieved from www.mfe.govt.nz/sites/default/files/urban-design-protocol-colour.pdf

Ministry of Health. (2013). Health loss in New Zealand: a report from the New Zealand Burden of Diseases, Injuries and Risk Factors Study, 2006–2016. Wellington, NZ: Ministry of Health.

Mitchell, R. (2013). Is physical activity in natural environments better for mental health than physical activity in other environments? *Social Science and Medicine, 91*, 130-134.

Mitchell, R. J., Richardson, E. A., Shortt, N. K., & Pearce, J. R. (2015). Neighborhood environments and socioeconomic inequalities in mental well-being. *American Journal of Preventive Medicine, 49*(1), 80-84.

Morgenstern, L. B., Escobar, J. D., Sánchez, B. N., Hughes, R., Zuniga, B. G., Garcia, N., & Lisabeth, L. D. (2009). Fast food and neighborhood stroke risk. *Annals of Neurology, 66*(2), 165-170.

Morland, K., Diez Roux, A. V., & Wing, S. (2006). Supermarkets, other food stores, and obesity: the atherosclerosis risk in communities study. *American Journal of Preventive Medicine, 30*(4), 333-339.

Müller-Riemenschneider, F., Pereira, G., Villanueva, K., Christian, H., Knuiman, M., Giles-Corti, B., & Bull, F. C. (2013). Neighborhood walkability and cardiometabolic risk factors in Australian adults: an observational study. *BMC Public Health, 13*, 755.

Mustafić, H., Jabre, P., Caussin, C., Murad, M. H., Escolano, S., Tafflet, M., Périer, M. C., Marijon, E., Vernerey, D., Empana, J. P., et al. (2012). Main air pollutants and myocardial infarction: a systematic review and meta-analysis. *JAMA, 307*(7), 713-721.

National Heart Foundation of Australia. (2009). Healthy by Design®: a guide to planning and designing environments for active living in Tasmania. Kingston, ACT. Retrieved from www.heartfoundation.org.au/images/uploads/publications/Healthy-by-Design-Tasmania.pdf

National Heart Foundation of Australia, Planning Institute Australia, & Australian Local Government Association. (2009). Healthy spaces & places: a national guide to designing places for healthy living. An overview. Kingston, ACT. Retrieved from www.healthyplaces.org.au/userfiles/file/HS&P%20An%20overview.pdf

National Institute for Health and Care Excellence. (2008). Physical activity and the environment. Public health guideline 8. London, UK: NICE. Retrieved from www.nice.org.uk/guidance/ph8/resources/physical-activity-and-the-environment-55460874949

Nutsford, D., Pearson, A. L., & Kingham, S. (2013). An ecological study investigating the association between access to urban green space and mental health. *Public Health, 127*(11), 1005-1011.

Ogilvie, D., Bull, F., Cooper, A., Rutter, H., Adams, E., Brand, C., Ghali, K., Jones, T., Mutrie, N., Powell, J., et al. (2012). Evaluating the travel, physical activity and carbon impacts of a 'natural experiment' in the provision of new walking and cycling infrastructure: methods for the core module of the iConnect study. *BMJ Open, 2*(1), e000694.

Ogilvie, D., Bull, F., Powell, J., Cooper, A. R., Brand, C., Mutrie, N., Preston, J., Rutter, H., & on behalf of the iConnect Consortium. (2011). An applied ecological framework for evaluating infrastructure to promote walking and cycling: the iConnect study. *American Journal of Public Health, 101*(3), 473-481.

Oliver, M., Mavoa, S., Badland, H., Parker, K., Donovan, P., Kearns, R. A., Lin, E. Y., & Witten, K. (2015a). Associations between the neighbourhood built environment and out of school physical activity and active travel: an examination from the Kids in the City study. *Health & Place, 36*, 57-64.

Oliver, M., Parker, K., Witten, K., Mavoa, S., Badland, H. M., Donovan, P., Chaudhury, M., & Kearn, R. (2016). Children's out-of-school independently mobile trips, active travel, and physical activity: a cross-sectional examination from the Kids in the City study. *Journal of Physical Activity & Health, 13*(3), 318-324.

Oliver, M., Witten, K., Blakely, T., Parker, K., Badland, H., Schofield, G., Ivory, V., Pearce, J., Mavoa, S., Hinckson, E., et al. (2015b). Neighbourhood built environment associations with body size in adults: mediating effects of activity and sedentariness in a cross-sectional study of New Zealand adults. *BMC Public Health, 15*, 956.

Oliver, M., Witten, K., Kearns, R. A., Mavoa, S., Badland, H. M., Carroll, P., Drumheller, C., Tavae, N., Asiasiga, L., Jelley, S., et al. (2011). Kids in the City study: research design and methodology. *BMC Public Health, 11*, 587.

Paquet, C., Coffee, N. T., Haren, M. T., Howard, N. J., Adams, R. J., Taylor, A. W., & Daniel, M. (2014). Food environment, walkability, and public open spaces are associated with incident development of cardio-metabolic risk factors in a biomedical cohort. *Health & Place, 28*, 173-176.

Park, S. K., & Wang, W. (2014). Ambient air pollution and type 2 diabetes: a systematic review of epidemiologic research. *Curr Environ Health Rep, 1*(3), 275-286.

Pearce, J., Blakely, T., Witten, K., & Bartie, P. (2007a). Neighborhood deprivation and access to fast-food retailing: a national study. *American Journal of Preventive Medicine, 32*(5), 375-382.

Pearce, J., Day, P., & Witten, K. (2008a). Neighbourhood provision of food and alcohol retailing and social deprivation in urban New Zealand. *Urban Policy and Research, 26*(2), 213–227.

Pearce, J., Hiscock, R., Blakely, T., & Witten, K. (2009a). A national study of the association between neighbourhood access to fast-food outlets and the diet and weight of local residents. *Health & Place, 15*(1), 193-197.

Pearce, J., Hiscock, R., Moon, G., & Barnett, R. (2009b). The neighbourhood effects of geographical access to tobacco retailers on individual smoking behaviour. *Journal of Epidemiology and Community Health, 63*(1), 69-77.

Pearce, J., Rind, E., Shortt, N., Tisch, C., & Mitchell, R. (2016). Tobacco retail environments and social inequalities in individual-level smoking and cessation among Scottish adults. *Nicotine & Tobacco Research, 18*(2), 138-146.

Pearce, J., Witten, K., Hiscock, R., & Blakely, T. (2007b). Are socially disadvantaged neighbourhoods deprived of health-related community resources? *International Journal of Epidemiology, 36*(2), 348-355.

Pearce, J., Witten, K., Hiscock, R., & Blakely, T. (2008b). Regional and urban-rural variations in the association of neighbourhood deprivation with community resource access: a national study. *Environment and Planning A, 40*, 2469-2489.

Pearce, N. (2000). The ecological fallacy strikes back. *Journal of Epidemiology and Community Health, 54*(5), 326-327.

Pereira, G., Foster, S., Martin, K., Christian, H., Boruff, B. J., Knuiman, M., & Giles-Corti, B. (2012). The association between neighborhood greenness and cardiovascular disease: an observational study. *BMC Public Health, 12*, 466.

Pereira, G., Wood, L., Foster, S., & Haggar, F. (2013). Access to alcohol outlets, alcohol consumption and mental health. *PloS One, 8*(1), e53461.

Pindus, M., Orru, H., & Modig, L. (2015). Close proximity to busy roads increases the prevalence and onset of cardiac disease--Results from RHINE Tartu. *Public Health, 129*(10), 1398-1405.

Power, M. C., Kioumourtzoglou, M. A., Hart, J. E., Okereke, O. I., Laden, F., & Weisskopf, M. G. (2015). The relation between past exposure to fine particulate air pollution and prevalent anxiety: observational cohort study. *BMJ, 350*, h1111.

Prüss-Ustün, A., Wolf, J., Corvalán, C., Bos, R., & Neira, M. (2016). Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks. Geneva, Switzerland: World Health Organization. Retrieved from www.who.int/quantifying_ehimpacts/publications/preventing-disease/en/

Public Health Advisory Committee. (2010). Healthy places, healthy lives: urban environments and wellbeing. Wellington, NZ: Ministry of Health. Retrieved from http://www.moh.govt.nz/NoteBook/nbbooks.nsf/0/9D4F66137506A543CC2577370072C7BE/$file/urban-environments-apr10.pdf

Pucher, J., Dill, J., & Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: an international review. *Preventive Medicine, 50 Suppl 1*, S106-125.

Rachele, J. N., Giles-Corti, B., & Turrell, G. (2016). Neighbourhood disadvantage and self-reported type 2 diabetes, heart disease and comorbidity: a cross-sectional multilevel study. *Annals of Epidemiology, 26*(2), 146-150.

Renalds, A., Smith, T. H., & Hale, P. J. (2010). A systematic review of built environment and health. *Family and Community Health, 33*(1), 68-78.

Richardson, E., Pearce, J., Mitchell, R., Day, P., & Kingham, S. (2010). The association between green space and cause-specific mortality in urban New Zealand: an ecological analysis of green space utility. *BMC Public Health, 10*, 240.

Richardson, E., Pearce, J., Mitchell, R., & Kingham, S. (2013). Role of physical activity in the relationship between urban green space and health. *Public Health, 127*(4), 318-324.

Richardson, R., Westley, T., Gariépy, G., Austin, N., & Nandi, A. (2015). Neighborhood socioeconomic conditions and depression: a systematic review and meta-analysis. *Social Psychiatry and Psychiatric Epidemiology, 50*(11), 1641-1656.

Riddell, T. (2005). Heart failure hospitalisations and deaths in New Zealand: patterns by deprivation and ethnicity. *New Zealand Medical Journal, 118*(1208), U1254.

Roh, S., Jang, Y., Chiriboga, D. A., Kwag, K. H., Cho, S., & Bernstein, K. (2011). Perceived neighborhood environment affecting physical and mental health: a study with Korean American older adults in New York City. *Journal of Immigrant & Minority Health, 13*(6), 1005-1012.

Ross, A., & Chang, M. (2014). Planning healthy-weight environments – a TCPA Reuniting Health with Planning Project. London, UK: Town and Country Planning Association and Public health England. Retrieved from www.tcpa.org.uk/pages/health.html

Rydin, Y., Bleahu, A., Davies, M., Dávila, J. D., Friel, S., De Grandis, G., Groce, N., Hallal, P. C., Hamilton, I., Howden-Chapman, P., et al. (2012). Shaping cities for health: complexity and the planning of urban environments in the 21st century. *Lancet, 379*(9831), 2079-2108.

Saarloos, D., Alfonso, H., Giles-Corti, B., Middleton, N., & Almeida, O. P. (2011). The built environment and depression in later life: the Health in Men Study. *American Journal of Geriatric Psychiatry, 19*(5), 461-470.

Sahlqvist, S., Goodman, A., Cooper, A. R., Ogilvie, D., & on behalf of the iConnect Consortium. (2013). Change in active travel and changes in recreational and total physical activity in adults: longitudinal findings from the iConnect study. *International Journal of Behavioral Nutrition and Physical Activity, 10*, 28.

Sahlqvist, S., Goodman, A., Jones, T., Powell, J., Song, Y., Ogilvie, D., & on behalf of the iConnect Consortium. (2015). Mechanisms underpinning use of new walking and cycling infrastructure in different contexts: mixed-method analysis. *International Journal of Behavioral Nutrition and Physical Activity, 12*, 24.

Sainsbury, P. G. (2013). Ethical considerations involved in constructing the built environment to promote health. *Journal of Bioethical Inquiry, 10*(1), 39-48.

Sallis, J. F., Cerin, E., Conway, T. L., Adams, M. A., Frank, L. D., Pratt, M., Salvo, D., Schipperijn, J., Smith, G., Cain, K. L., et al. (2016). Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. *Lancet, 387*(10034), 2207-2217.

Sallis, J. F., Cervero, R. B., Ascher, W., Henderson, K. A., Kraft, M. K., & Kerr, J. (2006). An ecological approach to creating active living communities. *Annual Review of Public Health, 27*, 297-322.

Sallis, J. F., Floyd, M. F., Rodríguez, D. A., & Saelens, B. E. (2012). Role of built environments in physical activity, obesity, and cardiovascular disease. *Circulation, 125*(5), 729-737.

Sallis, J. F., Spoon, C., Cavill, N., Engelberg, J. K., Gebel, K., Parker, M., Thornton, C. M., Lou, D., Wilson, A. L., Cutter, C. L., et al. (2015). Co-benefits of designing communities for active living: an exploration of literature. *International Journal of Behavioral Nutrition & Physical Activity, 12*, 30.

Salmond, C., Crampton, P., & Atkinson, J. (2007). NZDep2006 Index of Deprivation. Wellington, NZ: Department of Public Health, University of Otago. Retrieved from www.otago.ac.nz/wellington/otago020348.pdf

Scheepers, C. E., Wendel-Vos, G. C. W., Den Broeder, J. M., van Kempen, E. E. M. M., van Wesemael, P. J. V., & Schuit, A. J. (2014). Shifting from car to active transport: a systematic review of the effectiveness of interventions. *Transportation Research Part A: Policy and Practice, 70*, 264-280.

Schikowski, T., Adam, M., Marcon, A., Cai, Y., Vierkötter, A., Carsin, A. E., Jacquemin, B., Al Kanani, Z., Beelen, R., Birk, M., et al. (2014a). Association of ambient air pollution with the prevalence and incidence of COPD. *European Respiratory Journal, 44*(3), 614-626.

Schikowski, T., Mills, I. C., Anderson, H. R., Cohen, A., Hansell, A., Kauffmann, F., Krämer, U., Marcon, A., Perez, L., Sunyer, J., et al. (2014b). Ambient air pollution: a cause of COPD? *European Respiratory Journal, 43*(1), 250-263.

Schreckenberg, D., Griefahn, B., & Meis, M. (2010). The associations between noise sensitivity, reported physical and mental health, perceived environmental quality, and noise annoyance. *Noise & Health, 12*(46), 7-16.

Selander, J., Nilsson, M. E., Bluhm, G., Rosenlund, M., Lindqvist, M., Nise, G., & Pershagen, G. (2009). Long-term exposure to road traffic noise and myocardial infarction. *Epidemiology, 20*(2), 272-279.

Shah, A. S., Langrish, J. P., Nair, H., McAllister, D. A., Hunter, A. L., Donaldson, K., Newby, D. E., & Mills, N. L. (2013). Global association of air pollution and heart failure: a systematic review and meta-analysis. *Lancet, 382*(9897), 1039-1048.

Shah, A. S., Lee, K. K., McAllister, D. A., Hunter, A., Nair, H., Whiteley, W., Langrish, J. P., Newby, D. E., & Mills, N. L. (2015). Short term exposure to air pollution and stroke: systematic review and meta-analysis. *BMJ, 350*, h1295.

Shanahan, D. F., Bush, R., Gaston, K. J., Lin, B. B., Dean, J., Barber, E., & Fuller, R. A. (2016). Health benefits from nature experiences depend on dose. *Scientific Reports, 6*, 28551.

Shaw, C., Russell, M., van Sparrentak, K., Merrett, A., & Clegg, H. (2016). Benchmarking cycling and walking in six New Zealand cities: pilot study 2015. Wellington, NZ: New Zealand Centre for Sustainable Cities, University of Otago. Retrieved from http://sustainablecities.org.nz/wp-content/uploads/Benchmarking-cycling-and-walking-in-six-NZ-cities.pdf

Shortt, N. K., Tisch, C., Pearce, J., Richardson, E. A., & Mitchell, R. (2016). The density of tobacco retailers in home and school environments and relationship with adolescent smoking behaviours in Scotland. *Tobacco Control, 25*(1), 75-82.

Sommer, I., Griebler, U., Mahlknecht, P., Thaler, K., Bouskill, K., Gartlehner, G., & Mendis, S. (2015). Socioeconomic inequalities in non-communicable diseases and their risk factors: an overview of systematic reviews. *BMC Public Health, 15*, 914.

Song, Q., Christiani, D. C., XiaorongWang, & Ren, J. (2014). The global contribution of outdoor air pollution to the incidence, prevalence, mortality and hospital admission for chronic obstructive pulmonary disease: a systematic review and meta-analysis. *International Journal of Environmental Research and Public Health, 11*(11), 11822-11832.

Sport England, Public Health England, & David Lock Associates. (2015). Active design: planning for health and wellbeing through sport and physical activity. London, UK: Sport England. Retrieved from www.sportengland.org/facilities-planning/planning-for-sport/planning-tools-and-guidance/active-design/

Stafoggia, M., Cesaroni, G., Peters, A., Andersen, Z. J., Badaloni, C., Beelen, R., Caracciolo, B., Cyrys, J., de Faire, U., de Hoogh, K., et al. (2014). Long-term exposure to ambient air pollution and incidence of cerebrovascular events: results from 11 European cohorts within the ESCAPE project. *Environmental Health Perspectives, 122*(9), 919-925.

Statistics New Zealand. (2006). New Zealand: An urban/rural profile update. Updated data tables: people. Wellington, NZ. Retrieved from www.stats.govt.nz/browse_for_stats/Maps_and_geography/Geographic-areas/urban-rural-profile-update.aspx

Statistics New Zealand. (2008). Are New Zealanders living closer to the coast? Wellington, NZ. Retrieved from www.stats.govt.nz/browse_for_stats/population/Migration/internal-migration/are-nzs-living-closer-to-coast.aspx

Sugiyama, T., Neuhaus, M., Cole, R., Giles-Corti, B., & Owen, N. (2012). Destination and route attributes associated with adults' walking: a review. *Medicine and Science in Sports and Exercise, 44*(7), 1275-1286.

Sugiyama, T., Villanueva, K., Knuiman, M., Francis, J., Foster, S., Wood, L., & Giles-Corti, B. (2016). Can neighborhood green space mitigate health inequalities? A study of socio-economic status and mental health. *Health & Place, 38*, 16-21.

Sustrans. (2016). Fit for life. Independent research into the public health benefits of new walking and cycling routes. Bristol, UK: iConnect, Sustrans. Retrieved from www.sustrans.org.uk

The New York City Departments of Design and Construction, Health and Mental Hygiene, Transportation, and City Planning. (2010). Active design guidelines: promoting physical activity and health in design. New York: NYC. Retrieved from http://centerforactivedesign.org/dl/guidelines.pdf

Tomita, A., & Burns, J. K. (2013). A multilevel analysis of association between neighborhood social capital and depression: evidence from the first South African National Income Dynamics Study. *Journal of Affective Disorders, 144*(1-2), 101-105.

Vallée, J., Cadot, E., Roustit, C., Parizot, I., & Chauvin, P. (2011). The role of daily mobility in mental health inequalities: the interactive influence of activity space and neighbourhood of residence on depression. *Social Science and Medicine, 73*(8), 1133-1144.

Van Cauwenberg, J., De Bourdeaudhuij, I., De Meester, F., Van Dyck, D., Salmon, J., Clarys, P., & Deforche, B. (2011). Relationship between the physical environment and physical activity in older adults: a systematic review. *Health & Place, 17*(2), 458-469.

van den Berg, A. E., Maas, J., Verheij, R. A., & Groenewegen, P. P. (2010). Green space as a buffer between stressful life events and health. *Social Science and Medicine, 70*(8), 1203-1210.

Van Holle, V., Deforche, B., Van Cauwenberg, J., Goubert, L., Maes, L., Van de Weghe, N., & De Bourdeaudhuij, I. (2012). Relationship between the physical environment and different domains of physical activity in European adults: a systematic review. *BMC Public Health, 12*, 807.

Vandevijvere, S., Sushil, Z., Exeter, D. J., & Swinburn, B. (2016). Obesogenic retail food environments around New Zealand schools: a national study. *American Journal of Preventive Medicine, In press*.

Villanueva, K., Knuiman, M., Koohsari, M. J., Hickey, S., Foster, S., Badland, H., Nathan, A., Bull, F., & Giles-Corti, B. (2013). People living in hilly residential areas in metropolitan Perth have less diabetes: spurious association or important environmental determinant? *International Journal of Health Geographics, 12*, 59.

Wang, B., Xu, D., Jing, Z., Liu, D., Yan, S., & Wang, Y. (2014). Effect of long-term exposure to air pollution on type 2 diabetes mellitus risk: a systemic review and meta-analysis of cohort studies. *European Journal of Endocrinology of the European Federation of Endocrine Societies, 171*(5), R173-182.

Wang, Y., Chau, C. K., Ng, W. Y., & Leung, T. M. (2016). A review on the effects of physical built environment attributes on enhancing walking and cycling activity levels within residential neighborhoods. *Cities, 50*, 1-15.

Wasfi, R. A., Dasgupta, K., Orpana, H., & Ross, N. A. (2016). Neighborhood walkability and body mass index trajectories: longitudinal study of Canadians. *American Journal of Public Health, 106*(5), 934-940.

White, J. S., Hamad, R., Li, X., Basu, S., Ohlsson, H., Sundquist, J., & Sundquist, K. (2016). Long-term effects of neighbourhood deprivation on diabetes risk: quasi-experimental evidence from a refugee dispersal policy in Sweden. *Lancet Diabetes Endocrinol, 4*(6), 517-524.

Williams, J., Scarborough, P., Matthews, A., Cowburn, G., Foster, C., Roberts, N., & Rayner, M. (2014). A systematic review of the influence of the retail food environment around schools on obesity-related outcomes. *Obesity Reviews, 15*(5), 359-374.

Wilson, A. I. (2015). *Measuring the exposure to obesogenic environments among New Zealand school children. A thesis submitted in fulfilment of the requirements for a degree of Master of Science in Geography.* University of Canterbury, Christchurch, NZ. Retrieved from http://hdl.handle.net/10092/10847

Wilson, N., Blakely, T., Foster, R. H., Hadorn, D., & Vos, T. (2012). Prioritizing risk factors to identify preventive interventions for economic assessment. *Bulletin of the World Health Organization, 90*(2), 88-96.

Witten, K., Blakely, T., Bagheri, N., Badland, H., Ivory, V., Pearce, J., Mavoa, S., Hinckson, E., & Schofield, G. (2012). Neighborhood built environment and transport and leisure physical activity: findings using objective exposure and outcome measures in New Zealand. *Environmental Health Perspectives, 120*(7), 971-977.

Witten, K., Hiscock, R., Pearce, J., & Blakely, T. (2008). Neighbourhood access to open spaces and the physical activity of residents: a national study. *Preventive Medicine, 47*(3), 299-303.

World Health Organization. (2016). Cardiovascular diseases (CVDs). Fact sheet. from http://www.who.int/mediacentre/factsheets/fs317/en/

Yang, L., Sahlqvist, S., McMinn, A., Griffin, S. J., & Ogilvie, D. (2010). Interventions to promote cycling: systematic review. *BMJ, 341*, c5293.

Zapata-Diomedi, B., Brown, V., & Veerman, J. L. (2015). An evidence review and modelling exercise. The effects of urban form on health: costs and benefits. An evidence review commissioned by the Centre for Population Health, NSW Ministry of Health, and brokered by the Sax Institute for The Australian Prevention Partnership Centre. Australia. Retrieved from http://preventioncentre.org.au/wp-content/uploads/2015/07/1604_Urban-form-evidence-review_final1.pdf