Urban design, transport, and health 1

City planning and population health: a global challenge

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This is the first in a Series of three papers about urban design, transport, and health

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Significant global health challenges are being confronted in the 21st century, prompting calls to rethink approaches to disease prevention. A key part of the solution is city planning that reduces non-communicable diseases and road trauma while also managing rapid urbanisation. This Series of papers considers the health impacts of city planning through transport mode choices. In this, the first paper, we identify eight integrated regional and local interventions that, when combined, encourage walking, cycling, and public transport use, while reducing private motor vehicle use. These interventions are destination accessibility, equitable distribution of employment across cities, managing demand by reducing the availability and increasing the cost of parking, designing pedestrian-friendly and cycling-friendly movement networks, achieving optimum levels of residential density, reducing distance to public transport, and enhancing the desirability of active travel modes (eg, creating safe attractive neighbourhoods and safe, affordable, and convenient public transport). Together, these interventions will create healthier and more sustainable compact cities that reduce the environmental, social, and behavioural risk factors that affect lifestyle choices, levels of traffic, environmental pollution, noise, and crime. The health sector, including health ministers, must lead in advocating for integrated multisector city planning that prioritises health, sustainability, and liveability outcomes, particularly in rapidly changing low-income and middle-income countries. We recommend establishing a set of indicators to benchmark and monitor progress towards achievement of more compact cities that promote health and reduce health inequities.

Introduction

Significant global health challenges are being confronted in the 21st century, including increases in unhealthy diets, physical inactivity, non-communicable diseases (NCDs), injuries from road trauma, and obesity, combined with population growth, rapid urbanisation, and climate change, prompting repeated calls to rethink approaches to prevention.[1–5] Decisions about housing, food, water, energy, transport, social services, and health care[6] will profoundly affect the health, wellbeing, and safety of growing and ageing urban populations.[4,6,7] With the world's population estimated to reach 10 billion people by 2050, and 75% of this population living in cities,[5] city planning is now recognised as part of a comprehensive solution to tackling adverse health outcomes.[5]

Key messages

- Significant global health challenges are being confronted in the 21st century, and well planned cities that encourage walking, cycling, and public transport use have an important role to play in addressing these challenges
- Urban and transport planning and design can directly and indirectly affect non-communicable diseases, traffic injuries, and other adverse health and environmental outcomes
- Local and regional interventions can affect urban and transport planning and design, and these influence environmental, social, and behavioural risk exposures
- Integration of well implemented urban systems policies are needed to achieve healthy liveable cities
- Transport, planning and health ministers must develop appropriate legal, administrative, and technical frameworks contextualised to local conditions, to deliver compact pedestrian and cycling friendly cities that reduce private motor vehicle dependency
- City planning indicators are required to monitor progress within and between cities

Associations between city planning and health are not new. In the 19th century, planning curbed infectious disease outbreaks in industrialising cities through improvements in sanitation and housing and separation of residential areas from industrial pollution.[8,9] In the 21st century, well planned cities have the potential to reduce NCDs and road trauma and to promote health and wellbeing more broadly. This could be achieved by reducing automobile dependency, traffic exposure, pollution, noise, and urban heat-island effects, while enhancing mental health, contributing to climate change mitigation, and promoting walking and cycling in ways that are safe, comfortable, and desirable.

Leading global agencies recognise that city planning and management decisions affect the liveability of cities[6] and, ultimately, the health and wellbeing of residents. WHO recommends "placing health and health equity at the heart of [city] governance and planning",[10] highlighting the need for integrated urban planning, transport, and housing policy. This mirrors the Organisation for Economic Co-operation and Development's call for leadership from "transport, land use and health ministers" to create the "legal, administrative and technical frameworks" that promote walking.[11] Similarly, the UN has endorsed integrated

agendas to combat NCDs.[12] The UN's Sustainable Development Goals include promoting healthy lives and wellbeing by making cities inclusive, safe, resilient, and sustainable.[13] However, changing the way cities are planned, built, and managed will require bipartisan political leadership and community engagement.

In a rapidly urbanising world, understanding how urban and transport planning and design decisions affect health is important. City planners have traditionally focused on the physical, social, economic, and environmental aspects of where people live.[14] However, rapid changes in motorised transport have increased the geographical size of urban areas. Combined with unprecedented urban population growth, this change has put transport mobility at the forefront of city planning. Early in the 20th century, engineers began addressing traffic congestion and road trauma in European and North American cities. Transport engineering soon emerged as a new field, gaining political and economic influence with the construction of national motorway networks after World War 2. Transport planning followed as an engineering subfield.[15] City planning and transport planning are now typically run at all levels of government, but in separate agencies. Both are closely linked to political systems because they oversee major capital-intensive operations.[16] However, these disciplines currently operate in separate academic settings with their research underpinned by different theoretical approaches.[17]

This *Lancet* Series focuses on the health impacts of city planning through transport mode choices. Drawing on evidence from multiple disciplines and using critical and systematic reviews where available, in this, the first paper we review the published work and propose pathways through which urban and transport planning and urban design (together referred to as city planning) directly and indirectly affect NCDs, traffic injuries, and other adverse health outcomes. We also identify eight urban and transport planning and design interventions and consider their influence on eight environmental, social, and behavioural health risk exposures. The second paper in this Series[18] models some of the pathways through which city planning affects health. The third paper[19] focuses on research translation by considering how science can be, and is already being, used to guide city planning policy and practice that create compact cities that promote health.

Urban planning and transport interventions

Eight interventions to promote health

Urban planning and transport planning academics have long sought to understand ways to reduce motor vehicle kilometres travelled and encourage use of public transport and active transport modes such as walking and cycling.[20] These academics have identified six key built-form characteristics and related policies that are referred to as the 6Ds.[20] Building on this work, we identify eight integrated interventions that are needed to create cities that promote health (table 1). We also differentiate between urban and transport planning and design policies that determine regional and local outcomes.

At the regional level, urban and transport planning influences the availability and accessibility of employment and key destinations required for daily living (eg, food outlets, educational facilities, and health and community services), particularly by public transport. Urban and transport planning also manages demand for driving (eg, the ease and cost of driving and car parking) relative to active modes of transport. Local urban design and transport policies influence local neighbourhoods' structure, look, feel, and convenience (eg, street network design, availability of walking and cycling infrastructure, residential densities, the diversity and mix of land-use, and housing types); the desirability of neighbourhoods (eg, levels of crime and traffic safety); and public transport (eg, convenience, affordability, service frequency, safety, and comfort). Achievement of more compact sustainable cities that promote health requires integrated regional and local planning and design.

Pathways to better health through urban planning and design

The figure shows potential pathways through which city planning decisions influence the health and wellbeing of residents. Moving from left to right, the figure shows how eight urban system policies work together to create urban and transport planning and design interventions that directly and indirectly affect health by influencing daily living options and transport mode choices and demand. In turn, these interventions determine eight risk exposures related to NCDs, road trauma, and other adverse health outcomes. Next, these risk exposures determine intermediary outcomes (eg, greenhouse gas emissions and chronic disease risk factors) as well as traffic injury and disease outcomes, which ultimately determine quality of life and health, social, and environmental equity.

Urban environments and health inequities

According to WHO and UN Habitat's report *Hidden Cities*, all urban environments have the ability to produce health inequities that are "systematic, socially produced (and therefore modifiable), and unfair".[21] The nature and extent of these health inequities vary within and between countries, partly as a result of differing progress in nutritional, demographic, and epidemiological transitions. The socioeconomically disadvantaged have the highest rates of mortality and morbidity for most major causes of death, including infectious diseases, NCDs, and traffic injuries.[10] Independent of individual socioeconomic position (compositional factors),[22] characteristics of the places in which people live (contextual factors) affect health inequities (figure).[23,24]

	Urban and transport planning and design features	Examples
Regional planning		
Destination accessibility	Regional employment, facilities, and services conveniently accessible by public transport; destinations for daily living available locally	Jobs, facilities, and services within 30 min travel from home by public transport; daily living destinations within walking distance
Distribution of employment	An appropriate mix of employment available across a region	A job–housing balance from 0·8 to 1·2
Demand management	Parking supply and pricing policies increase the attractiveness of using alternative travel modes to driving	Building codes and other government policies that minimise car parking
Local urban design		
Design	Urban design creates walkable catchments around activity centres and incorporates accessible public open space; street networks minimise distances between homes and daily living destinations, reduce traffic exposure, and create safe pedestrian, cycling, and public transport networks; lot* layouts designed to increase residential densities and promote natural surveillance	High street connectivity including ped-sheds ≥0·6 within 0·8–1·2 km (ie, 1–15 min walk) of activity centres, transport hubs, and schools; separated pedestrian and cycle paths; local public open space provided; housing overlooks streets and public open spaces
Density	Residential densities sufficient to support the viability of local business and high-frequency public transport services	Multiunit housing built around activity centres with shops, services, and transport hubs
Distance to public transport	High-frequency public transport located within short walking distances from homes	Bus stops accessible ≤400 m; rail stops accessible ≤800 m from homes
Diversity	Residential areas built with different types of housing mixed with commercial, public, and recreational opportunities	Different types of housing available near, around, and on top of shops and services required for daily living
Desirability	Neighbourhoods designed to be safe, attractive, and accessible; public transport that is convenient, affordable, frequent, safe, and comfortable	Crime prevention design principles incorporated into residential and commercial developments; urban greening strategies implemented; traffic minimised, calmed, and separated from pedestrians and cyclists, particularly near schools

*Also known as plots in some countries, including those in the UK.

Table 1: **Urban and transport planning and design interventions and features required to create compact cities that enhance health and wellbeing**

Risk exposures influenced by city planning

Traffic exposure

Here we consider evidence for eight environmental, social, and behavioural risk exposures related to urban and transport planning and design decisions (figure), which in turn affect NCDs, injuries, and other adverse health outcomes.

Private motor vehicle sales are often used as an indicator of economic growth, development, and modernisation. However, a higher reliance on private motor vehicles increases traffic volumes and road trauma,[25,26] resulting in injury and early death.[27] Road traffic injuries are the eighth leading cause of disability-adjusted life years (DALYs) worldwide, and, in some LMICs, road traffic injuries are the second leading cause of DALYs, with young people bearing the greatest burden.[28] Between 1990 and 2010, overall global DALYs due to pedestrian injuries increased by more than those for other transport injuries.[7] Indeed, deaths from road transport injuries exceed those from HIV/AIDS, tuberculosis, and malaria.[29] By 2030, road traffic injury-related DALYs are estimated to be more than ten-times those of tuberculosis and malaria combined and twice those of HIV/AIDS.[30]

Urban and transport planning and design decisions directly affect the need for private motor vehicles by determining the location of housing in relation to employment, education, and the services required for daily living. These decisions affect travel distances and, in the absence of convenient transport options, traffic volumes, both of which are related to road trauma.[31] Although the risk of collision increases with higher vehicular traffic volume and increased population density,[32] once a critical mass of walking or cycling is achieved, the collision rate falls, although the overall number of injuries and deaths might still rise.[33]

In high-income and middle-income countries, efforts to improve traffic safety have focused mainly on safe road design for private vehicles, vehicle crashworthiness, and modifying driver behaviour (eg, driving at slower speeds and not driving while impaired).[34] Land-use and transport planning that reduces automobile dependence and decreases vehicle kilometres travelled can also reduce the risk of road trauma.[35,36]

The health burden of motor vehicle-related injuries continues to disproportionately affect active transport users (as discussed in this Series[18]) and those without access to a vehicle, including poor, young, and older people.[37,38] Concerns about traffic and road safety are a major deterrent to parents permitting children to use active travel modes.[39] In high-income countries, such as the USA and Australia, many city streets have become child-free zones,[39] with rapid declines in the number of children using active transport modes to travel to and from school and around their neighbourhoods.[40,41]

In several countries (eg, Germany, France, The Netherlands, and Sweden), injury and fatality rates for active transport users have been reduced by more than 70% (from 1975 to 2001).[42,43] These countries have implemented new laws of strict liability, where vulnerable road users (not drivers) are assumed to be innocent. These countries have also lowered speed limits in towns and cities to 30 km/h; introduced high-quality transport systems; introduced demand management strategies, including reduced car parking; devised protective road

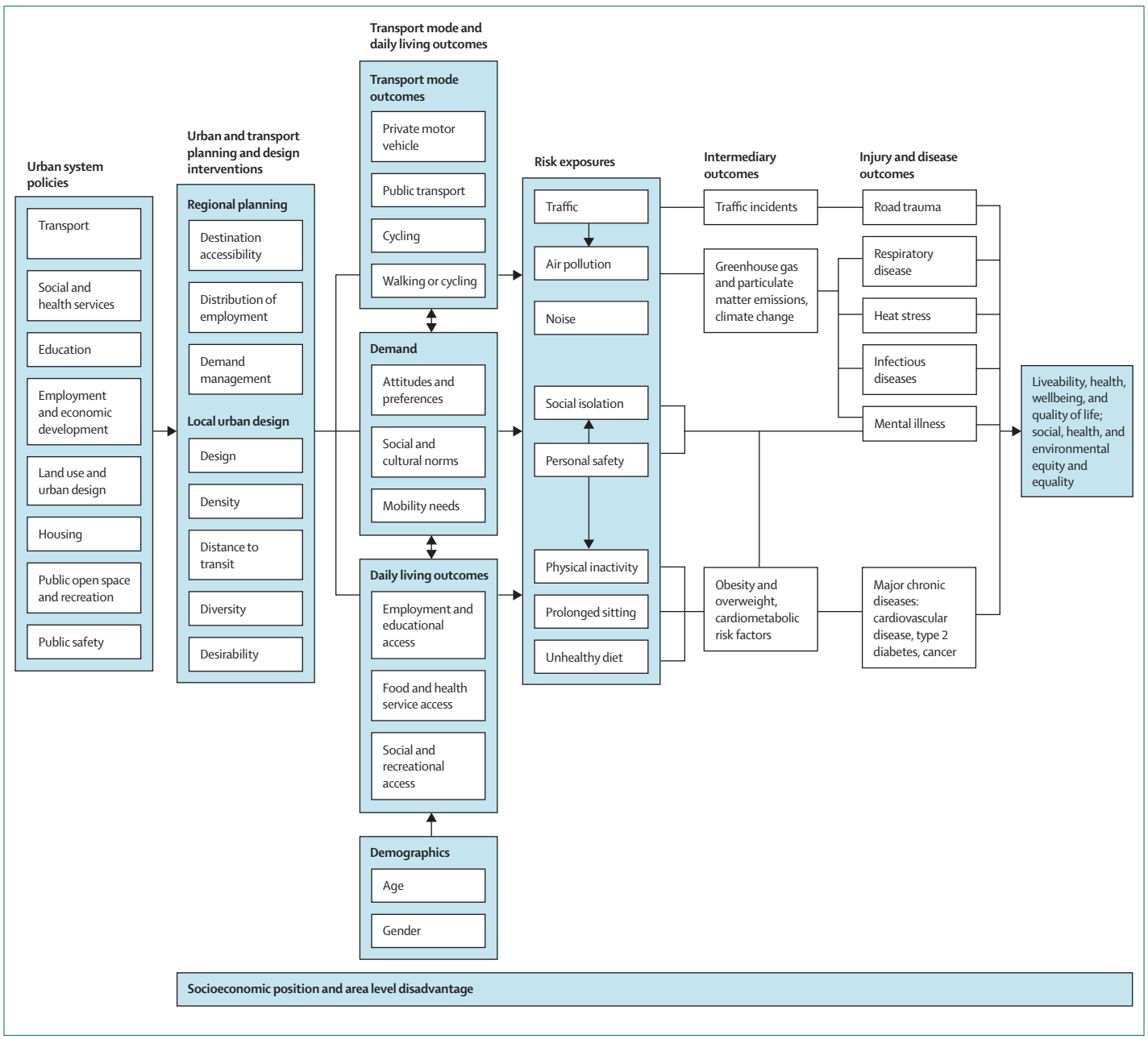

***Figure*: Direct and indirect pathways through which urban and transport planning and design decisions influence health and wellbeing**

designs that reduce conflicts between pedestrians, cyclists, and drivers; and improved traffic signals.[44,45] These practices could be trialled elsewhere to reduce the global burden of road injury while also increasing the demand for active travel and reducing NCD risks.

Air pollution

Several meta-analyses and reviews show a relationship between air pollution exposure and health impacts, including the incidence and prevalence of childhood asthma and wheeze,[46] asthma exacerbation,[47] impaired lung function,[48] cardiovascular mortality and morbidity,[48,49] all-cause mortality,[47,48] hospital admissions,[48] and restricted physical activity.[48] The global disease burden attributed to ambient particulate matter pollution from all sources remained stable between 1990 and 2010, at approximately 3% of DALYs.[50] However, concerns are growing about urban air pollution in LMICs caused by increasing population concentrations, industrial pollution, burning of solid

fuels, and the unprecedented rise in motor vehicle ownership.[51,52]

Motor vehicle traffic exposure is a major source of air pollution in both high-income countries and LMICs. People living within 300 m of busy roads are exposed to higher levels of pollutants, including particulate matter, carbon monoxide, and nitrogen oxide.[53] Cars are typically older in LMICs and generate higher emissions than cars in high-income countries.[54]

The transport sector also indirectly affects health through climate change pathways by accounting for 25% of global carbon dioxide emissions; 75% of which arise from road transport.[55] Policies to create a multimodal transport road system that prioritises walking, cycling, and public transport use would substantially reduce urban air pollution and greenhouse gas emissions, producing a range of environmental and health benefits.[4,55]

Physical activity outdoors, including walking and cycling, can increase exposure to air pollution.[56] However, air pollution exposure is substantial for car occupants and is higher for those in cars than for cyclists travelling through the same environment.[57,58] Other research suggests that the health benefits of cycling outweigh the risks from air pollution exposure.[59,60]

City planning can assist by setting homes, schools, parks, and exercise facilities away from heavily trafficked roads and by separating cycle lanes from motor vehicle traffic.[56] To protect residents from increased air pollution exposure risk, greater consideration needs to be given to the design of higher density housing sited on heavily trafficked roads.[61]

Noise

Chronic noise exposure has implications for physical and mental health through annoyance, sleep disturbance, and chronic stress pathways.[62] Road traffic noise is the most important source of ambient noise exposure worldwide.[62–64] A recent meta-analysis concluded that traffic noise in Europe caused between 400 and 1500 DALYs per million population.[65]

Road traffic noise exposure influences physical health outcomes such as cardiovascular disease and hypertension,[64,66-68] and airport noise is associated with reduced quality of life, impaired cognitive development in children,[66] and reduced psychological wellbeing.[69] However, most of the studies included in reviews have been cross-sectional.

The health impacts of noise exposure could be ameliorated by setting homes, schools and other services away from heavily trafficked routes; reducing and slowing road traffic; using noise abating road-surfacing materials; and designing housing to improve sound attenuation, including locating bedrooms and balconies away from noise sources.[61,64]

Social isolation

Loneliness and social isolation are associated with worse mental health,[70] adverse health behaviours (eg, physical inactivity and smoking), and detrimental biological processes (eg, higher blood pressure and C-reactive protein, and poorer immune functioning) compared with regular social contact.[71] A 2015 meta-analysis concluded that the impact of social isolation on premature mortality was comparable to other established health risk factors (eg, obesity), highlighting its importance as a public health issue.[71]

Evidence suggests that urban design and planning can encourage social interactions and cohesion,[58] and have subsequent health benefits.[70] The design of streets and public open spaces can encourage residents to stop, linger, and interact.[58] Accessible and diverse destinations and transport options increase walking trips, which in turn have been linked to unplanned social encounters and sense of community.[58] Neighbourhood destinations also provide settings for cultural and informal social activities that can enhance community connections and sense of belonging.[58] However, sufficient residential densities are required to create vibrant neighbours.[61]

As cities grow and densify, a challenge is to create urban environments with sufficient density and local amenities to promote walking and social interactions, while also protecting residents from the high activity levels created by dense neighbourhoods.[58] There is little understanding about the optimum density to promote social contact while mitigating other urban exposures, particularly in more vulnerable and low-income populations. These urban design attributes are insufficient to reduce social isolation if the neighbourhood is regarded as undesirable (ie, it is unsafe or poorly maintained). Poor neighbourhood upkeep can signal a breakdown of social control and has been associated with increased crime and a fear of crime.[72]

Safety from crime

Crime can affect NCDs because people might constrain their own, and their children's, social and physical activities to avoid places or situations they perceive to be unsafe.[73,74] Although evidence is mixed, the associations of crime-related safety and physical inactivity with increased obesity levels are more consistent for groups who perceive themselves to be physically vulnerable to crime (eg, women and older adults) or who are economically vulnerable to crime (eg, low-income and minority populations).[73,75] Low-income groups are exposed to more neighbourhood crime and disorder; they are typically more fearful but often have no alternative to walking for transport,[73] which might partly explain mixed research findings.[73] Crime and the fear of crime also have associations with mental health, but there is less clarity on the causal direction.[76]

Shopping centres, transport nodes, and street connectivity result in more people walking and circulating locally, but have also been associated with opportunistic crime such as property crime (eg, burglaries, vandalism). Liquor stores and drinking

venues have been associated with higher levels of alcohol consumption and violent crime.[77] Yet neighbourhoods with diverse and accessible destinations and transport options encourage locals to walk, which enhances natural surveillance, in turn, making people feel safer. Encouraging more so-called eyes on the street is central to an approach to crime prevention that incorporates urban design principles, aiming to reduce opportunities for criminal behaviours.[77] Although more eyes on the street are generally interpreted as a source of safety, any benefit depends on whether these people are viewed as accepted users of the space.[78]

Notably, the incidence of crime does not necessarily mean that people feel unsafe or fearful.[76] The presence of physical disorder that typically clusters near non-residential land-use and vacant land has associations with heightened safety concerns.[72] These relationships can be exacerbated for low-income populations who often live in neighbourhoods with concentrated deprivation and have fewer financial resources to buffer themselves from real (or perceived) threats to safety.[72] Furthermore, low-income neighbourhoods can be marred by additional safety hazards (eg, unattended dogs and heavy and high-speed traffic).[75]

Physical inactivity

Physical inactivity and unhealthy diets are the largest contributors to NCDs, and much of the evidence on city planning and health has focused on physical activity. In 2010, about 3·2 million deaths annually were attributed to being insufficiently active, causing 69·3 million global DALYs.[79] Physical inactivity increases the risk of major NCDs, including coronary heart disease, type 2 diabetes, colon cancer, and breast cancer, as well as reducing life expectancy.[80] Land-use and transport planning decisions can influence the convenience, attractiveness, and safety of walking and cycling for transport, as well as the opportunities for, and desirability of, recreational physical activity.

Walking and cycling can serve both transportation and recreational purposes, and both modes can reduce private motor vehicle dependency. Walking and cycling often, but not always, need different infrastructure. Walking is more common than cycling and typically needs less skill, equipment, and infrastructure. However, cycling allows longer distances to be travelled in less time, thereby reducing time spent commuting and increasing access to amenities. Cycling rates are much higher in European cities where cycling-friendly policies and infrastructure investments have been implemented compaired with North America and Australia.[44]

Urban planning and design that creates neighbourhoods with connected street network patterns, combined with zoning to support mixed-use and higher-density development (ie, walkable neighbourhoods), promotes walking for transport.[20, 81–84] Creating cities that facilitate physical activity as part of daily utilitarian activities can promote health and prevent NCDs. By contrast, low-density urban fringe residential development with poor access to shops, services, and public transport fosters automobile dependence and reduces physical activity opportunities.

The evidence for recreational walking is less consistent. Neighbourhood desirability (eg, its aesthetics, levels of traffic, and real and perceived safety from crime and disorder) and access to public open space is inconsistently associated with recreational walking,[81,82,85] particularly in studies relying on perceptions rather than objective measures. One review reported that, although there was only moderate evidence that access to parks and aesthetics encouraged recreational walking, all studies that measured the quality of recreational destinations reported positive associations with recreational walking.[85] Indeed, access to high-quality green space has also been shown to enhance both physical and mental health.[86–90] As cities grow and become more compact, preserving and increasing high-quality public open space will become important as access to private yards and gardens declines.[61]

Prolonged sitting

Sedentary behaviours—ie, too much sitting, as distinct from too little physical activity—have emerged as a new concern for chronic disease prevention[91,92] and are associated with increased risk of type 2 diabetes, cardiovascular disease, some cancers, and all-cause mortality.[93,94] Urban-dwelling working adults can sit for 10 h or more per day, which increases health risks, even among those who meet physical activity guidelines.[95,96] Prolonged periods of sitting includes time spent in cars and can be associated with increased cardiovascular disease risk[97,98] and poorer mental health.[99]

In high-income countries, time in cars, television viewing, and other screen use account for up to 85% of adults' non-occupational sitting time.[100] Worldwide, sedentary behaviours are rapidly rising as LMIC shift from agricultural to manufacturing and service economies with increased use of labour-saving devices and more motorised forms of transport.[101]

Urban design and planning attributes (particularly for density, diversity of land-use, availability of multiple local destinations, and distance to transport and local amenities that provide a range of more active choices for daily living options), can help to reduce sitting time.[102, 103] A recent review of 17 studies identified 89 associations between environmental attributes and sedentary behaviours; the most consistent finding was that people living in large urban areas spend less time sedentary than do those living in smaller towns or cities.[104] Large urban areas of high-income countries often have more extensive public transport infrastructure, which allows more residents to spend less time sitting in private vehicles. Given the rapid changes being observed globally, research is needed in this emerging area.

Unhealthy diets

Worldwide 2·6 million deaths a year are attributable to insufficient fruit and vegetable intake,[105] and an estimated 2·1 billion people are overweight or obese.[106] A growing evidence base has examined the relationship between food purchasing, diets, and urban food environment land-use characteristics: food *availability* (ie, food supply) and food *accessibility* (ie, food supply location and physical proximity).[107] The availability[107] and variety[108,109] of healthy food are consistently and positively associated with better diets, with supermarket density related to higher fruit and vegetable consumption.[108] Conversely, fast-food availability is positively associated with fast-food purchasing,[109] fast-food consumption,[110] and obesity risk,[111] and these are strongly associated with socioeconomic disadvantage.[112]

The evidence linking health and food accessibility (as measured by proximity) is less consistent, especially for fast-food access.[107] In urban settings, supermarket proximity has been associated with higher fruit and vegetable intake and reduced prevalence of obesity,[113] even for people with no private motor vehicle access.[108] Conversely, living in areas with poor access to healthy and affordable food might require residents without accessible public or private transport to shop in smaller local stores with limited variety, poorer quality, and higher prices, thereby compromising food security and potentially widening inequities.[114,115]

Preservation of local arable land is crucial for the long-term food supply.[116] To feed the world's growing population will need up to 100% more food by 2050.[117] Consequently, land-use policies that protect and support agriculture in urban and peri-urban settings are essential to reduce inequities by facilitating access to local food.[116,117]

Implications of urban planning and design initiatives in LMICs

Translation of evidence from high-income countries into appropriate policies for LMICs, where urban environments often differ greatly, can be challenging. For example, in most middle-income countries, overall density patterns are considerably higher[118] and cities tend to be more compact and monocentric (with jobs, cultural opportunities, and activities located mainly in the city centre).[119] Urban residents in LMICs also depend heavily on informal and relatively inexpensive on-demand transport services (eg, private taxis, buses, cycles, motorcycles, and rickshaws).[120,121] These informal services often contribute to congestion, air pollution, and reduced traffic and personal safety. Finally, compared with both high-income and middle-income countries, low-income countries tend to have lower degrees of urbanisation, fewer employment opportunities, and poorer availability and quality of public services (eg, public transportation).[122]

Insufficient separation of pedestrians and motorised transport, particularly in LMICs, reduces pedestrian safety and increases road trauma. Additionally, rapid urbanisation combined with a lack of adequate traffic regulation results in a large and growing burden of disease associated with road injuries, road deaths,[7] and high crime rates.[123]

Greater social inequities are also observed between and within all LMIC.[124] These factors include inequities in access to the basic building blocks of health-promoting urban development (eg, sanitation, adequate housing)[125] as well as higher order infrastructure and services that create health and wellbeing and make cities liveable (eg, access to public open spaces, education, and health services).[124] These urban challenges now feature in the UN's Sustainable Development Goals.[13]

While walking for commuting purposes is usually more prevalent among urban populations in LMICs,[126] access to health services, sanitation, clean water, and adequate housing is less common.[124,127] In many Asian and African countries, powered two-wheelers (motorbikes and scooters) are the preferred low-cost high-mobility vehicles for both commercial and personal purposes, contributing to high rates of road trauma.[29] The popularity of electric bikes could help to reduce air pollution and ambient noise levels, thereby addressing some of the health impacts of motorised traffic in cities.[128] However, if powered two-wheeler travel is substituted for walking, this will reduce physical activity, increase obesity,[129] and increase the already growing levels of road trauma. For example, in China, rapid increases in motorisation in the 1990s saw a doubling of obesity in men (but not women) whose households gained a motor vehicle.[129] Further, LMICs have seen substantial recent changes to their food supply chains, moving from subsistence farming to processed foods from supermarkets and convenience stores.[116] Hence, complex interactions are at play when planning cities to improve health in LMICs.

So far there is little evidence from LMICs[130,131] from which other cities and countries can learn. Over recent decades, several Latin American cities (eg, Curitiba, Brazil; Bogotá, Colombia; and Mexico City, Mexico) have implemented extensive bus rapid transit systems,[120] which have overcome transport inequities and improved access to public services (eg, health care)[132] and employment opportunities, as well as increasing physical activity levels.[133,134] Additionally, affordable housing programmes have reduced the proportion of people living in slums and degraded areas,[135] and increased access to clean water, sanitation, and transport. In recent years, cycle-sharing programmes have been established in many Latin American cities.[120] From 1993 to 2007, China (the country with the largest number of cycles and cyclists) had a drastic decline in cycle ownership (from 197 cycles per 100 households to 133 cycles per 100 households).[136] However, since 2005, large-scale cycle-sharing programmes have been implemented in most of China's major cities.[137]

The potential for initiatives to increase inequities must also be considered. In Latin America, although small

increases in bicycle use have been observed, most bicycle-share programmes are implemented in socioeconomically advantaged areas.[120] Similarly, in Hangzhou, China, members of bicycle-share programmes were found to have a higher rate of car ownership than non-members, probably because those who did not have a car used their own bicycles.[136] Additionally, many housing projects implemented in Latin America lack integrated planning, resulting in limited access to services.[120] Finally, the implementation of large-scale projects (eg, Olympics in Beijing and Rio de Janeiro) could improve outcomes in some areas (eg, access to public transport) but increase inequities (eg, displacement of low-income residents to outer suburbs with no public transport and amenities).

Hence, in LMICs, there is potential for health inequities to widen if insufficient attention is paid to integrated land-use, transport, housing, and infrastructure legislation and planning. The poor resources and the rate of economic and societal change can make integrated planning in LMICs seem challenging. However, integrated planning could optimise the use of existing resources and help to avoid unintended consequences, particularly those of large-scale interventions, which should be well evaluated both before and after implementation.

Discussion

The escalating personal, social, and economic burden imposed by rapidly rising rates of NCDs and their risk factors,[12] together with the health and societal impacts of climate change,[4] will produce immense human and environmental harm that threatens to undermine global social and economic development and security.[12] Between now and 2030, an estimated US$58 trillion is needed worldwide to upgrade, maintain, and develop urban infrastructure to meet growing demand and the challenges of the 21st century.[138]

Designing pedestrian-friendly and cycling-friendly cities will help to reduce inequities and produce co-benefits across multiple sectors,[139,140] including health, traffic management, environment (mobility, air quality, energy, water, and climate change), and the economy.[141] Better planned and designed cities will help to build communities by decreasing commute and mandatory travel times away from one's neighbourhood.[142]

City planning is therefore an essential element of a multilevel, multisector response to face the major global health challenges of the 21st century. Appropriate legal, administrative, and technical urban planning and design frameworks are urgently needed to create more compact cities that facilitate active travel modes to promote health and lower greenhouse gas emissions.[4, 143]

We identified eight integrated regional and local urban and transport planning and design interventions to influence transport mode choices. Land-use, transport, and infrastructure interventions and policies interact to create a built form that affects the feasibility and attractiveness of using active travel modes.[144] We have argued that travel mode choices affect health through their impact on eight environmental, social and behavioural risk exposures.

Creating cities that produce health and wellbeing outcomes needs both regional and local policies that prioritise walking, cycling, and public transport use over private motor vehicle travel. At the local level, good urban design will only be fully effective if supported by well-implemented city-wide and region-wide integrated policies that create accessible employment, education, services, and high-quality public transport.[145]

Changing the entrenched patterns of automobile-centric urban development that are contributing to the NCD pandemic, road traffic injuries, and other adverse health outcomes needs broad social, political, and economic changes as well as multisector involvement. Although integrated land-use and transport planning is vital, land use and transport are typically planned by different agencies and studied by different disciplines.[146] These institutional and disciplinary disconnections are at the heart of many of the health risk exposures and outcomes identified in our model. A consortium of European countries is already taking steps to address the need for co-ordination across sectors.[146] However, as suggested by the Organisation for Economic Co-operation and Development,[11] leadership from transport, planning, and health ministers is urgently needed to facilitate action and overcome barriers.

Academic leadership is also needed. This includes interdisciplinary research and expanding interdisciplinary tertiary and workforce development programmes that bring together health and the built environment fields.[147] However, mobilising and supporting community engagement and action is also critical.[148] Local citizenry could influence both political and private sectors by demanding urban planning and design that facilitates walking, cycling, and public transport.

Transport is a determinant of health that contributes to the existence, persistence, and (sometimes widening of) health inequities within and between cities.[141] In cities around the world, the mobility benefits afforded by private and public motorised travel are less accessible to the poor and disadvantaged (including elderly, disabled, and young people) who are also more likely to experience the externalised costs of motor vehicle dependency (eg, exposure to noise, pollution, and road trauma).[21,149–151] Urban and transport planning must therefore prioritise policies, infrastructure, and services that favour the most socioeconomically disadvantaged populations.

There is a need to benchmark and monitor progress on the implementation of policies, and to track changes in health impacts. WHO has proposed a set of urban indicators to reduce inequities.[152] We extend this work in table 2 in which we set out city planning indicators and outcomes that could be used to compare within and between cities.

	Indicator
Legislation and policies	
Integrated transport and urban planning	Federal and state transport and urban planning legislation requires integrated transport and urban planning actions to create healthy and sustainable cities and regular review of progress
Air pollution	Federal and state air pollution legislation seeks to protect and enhance air quality to promote the health of urban populations
Destination accessibility	Federal and state transport and urban planning legislation requires coordinated planning of transport, employment, land use, and infrastructure that ensures access by public transport
Distribution of employment	Urban planning and design codes that require a balanced ratio of jobs to housing (eg, 0·8–1·2)
Demand management	Urban planning, building codes, and local government policies limit car parking; price parking appropriately for context
Design	Urban design codes create pedestrian-friendly and cycling-friendly neighbourhoods, requiring highly connected street networks (eg, ped-sheds^2 ≥0·6 within 0·8–1·2 km);* pedestrian and cycling infrastructure provision;† public open space; lot layouts that maximise natural surveillance
Density	Urban design codes require minimum and maximum context-specific housing densities, including higher density development around activity centres and transport hubs
Distance to public transport	Urban design codes require frequent service public transport to be within 400–800 m of residential walkable catchments
Diversity	Urban design codes require a diverse mix of housing types and local destinations needed for daily living
Desirability	Urban design codes incorporate crime prevention through urban design principles, manage traffic exposure† and establish urban greening provisions
Government transport investment	
Transport infrastructure investment by mode	Percentage of total government transport expenditure in a given financial year spent on pedestrian infrastructure, cycling infrastructure, public transport, and road infrastructure
Urban and transport planning and design interventions	
Public transport access	Percentage population living within 400–800 m of high-frequency public transport
Employment	Percentage of population with employment within ≤30 min of their home by walking, cycling, or public transport
Distribution of employment	Jobs to housing ratio
Transport infrastructure	Ratio of roads (km) to footpaths (km) and designated cycle lanes (km)
Density	Dwellings or area within 1·2 km of activity centres and public transport hubs, and in urban fringe developments
Distance to transit	Percentage of population living within 400 m of a bus stop and 800 m of a rail stop.
Destinations	Percentage (urban) land area allocated to destinations required for daily living
Open or green space	Percentage (urban) land area allocated to open or green space
Transport outcomes	
Trip mode share	Proportion of total and commuting trips made by walking, cycling, public transport, and private motor vehicle
Risk exposure outcomes	
Road trauma	Road death and injury rate expressed as the number of cases per 100 000 population; proportion of road injuries and deaths involving pedestrians and cyclists
Respiratory conditions	Number of respiratory-related hospital admission cases per 100 000 population
Physical activity	Prevalence of insufficient physical activity, expressed as a percentage of adults, adolescents, and children who are physically inactive
Diet	Prevalence of adults, adolescents, and children consuming ≥5 servings of fruit and vegetables a day
Obesity	Percentage of adult, adolescent, and child population classified as overweight or obese

*Particularly within walking distance of shops, services, and transport hubs. †Ratio of straight line distance buffer or street network distance buffer. Adapted and expanded from WHO.[153]

Table 2: **Indicators that could be used to monitor progress towards the implementation of urban and transport legislation, policies, investment, and outcomes to create cities that enhance health and reduce non-communicable diseases**

This Series paper has a few limitations. Although the evidence presented on how multiple aspects of urban form can affect health is relatively consistent, most studies are cross-sectional and done in high-income countries. How findings translate in LMICs is yet to be determined. Stronger longitudinal evidence is needed across the board, particularly from natural experiment studies of policy interventions[153–156] that would allow policy impacts to be monitored to learn what works in different contexts, particularly in LMICs experiencing rapid changes in patterns of urbanisation.[145] These studies would provide an early warning system of any unintended consequences of new policies, enabling them to be modified to achieve desirable health outcomes. In this paper we sought to raise issues and explore a wide range of pathways requiring further investigation. Although we drew on systematic reviews and meta-analyses where available, we undertook a narrative, rather than a formal systematic review. Finally, many issues were not considered here, but could be investigated in the future. These include the impact of planning decisions on other risk exposures (eg, alcohol consumption and gambling) and gender freedom or safety on public transport.

Legal, administrative, and technical frameworks contextualised to local conditions are needed to deliver compact pedestrian-friendly and cycling-friendly cities that reduce private motor vehicle dependency. Although the final mix of urban and transport planning and design interventions will vary, the overall goal must be to create cities that reduce NCDs, road injuries, and other adverse

health risks through promotion of active lifestyles and protection of citizens from traffic, environmental pollution, noise, crime, and violence. Achievement of healthier and more compact cities will need well implemented regional and local planning policies that integrate planning for land use, transport, housing, economic, and infrastructure with urban design.

Contributors

BG-C, RR, GT, JFS, and MS conceptualised the paper. BG-C, AV-M, RR, GT, ALD, HB, SF, ML, and NO drafted sections. BGC, AVM and NO responded to critical review. All authors reviewed the literature and critically edited the Series paper.

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References

1 Beaglehole R, Bonita R, Horton R, et al. Measuring progress on NCDs: one goal and five targets. *Lancet* 2012; **380:** 1283–85.
2 Das P, Horton R. Rethinking our approach to physical activity. *Lancet* 2012; **380:** 189–90.
3 Kleinert S, Horton R. Rethinking and reframing obesity. *Lancet* 2015; **385:** 2326–28.
4 Watts N, Adger WN, Agnolucci P, et al. Health and climate change: policy responses to protect public health. *Lancet* 2015; **386:** 1861–914.
5 UNFPA. State of world population 2010. New York: United Nations Population Fund, 2011.
6 Badland H, Whitzman C, Lowe M, et al. Urban liveability: emerging lessons from Australia for exploring the potential for indicators to measure the social determinants of health. *Soc Sci Med* 2014; **111:** 64–73.
7 Murray CJL, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; **380:** 2197–223.
8 Corburn J. Reconnecting with our roots. American urban planning and public health in the twenty-first century. *Urban Aff Rev Thousand Oaks Calif* 2007; **42:** 688–713.
9 Hall P. Cities of tomorrow. Oxford: Blackwell Publishers; 1996.
10 World Health Organization, Commission on the Social Determinants of Health. Closing the gap in a generation: Health equity through action on the social determinants of health. Final report of the Commission on the social determinants of health. Geneva: World Health Organization; 2008.
11 International Transport Forum. Pedestrian safety, urban space and health: research report summary document. Paris, France: International Transport Forum, OECD; 2011.
12 United Nations. Sixty seventh session Political Declaration of the High-level Meeting of the General Assembly on the prevention and control of non-communicable diseases. 2011. http://www.un.org/ga/search/view_doc.asp?symbol=A/66/L.1 (accessed Sept 6, 2015).
13 United Nations. Post-2015 development agenda. Geneva: United Nations; 2015.
14 Abu-Lughod JL. Changing Cities: Urban Sociology. New York: Harper Collins; 1991.
15 Lay MG. The History of Transport Planning. In: Hensher DA, Button KJ, editors. Handbook of Transport Strategy, Policy and Institutions. London: Elsevier, 2005: 157–74.
16 Dimitriou HT, Gakenheimer R. Urban Transport in the Developing World, A Handbook of Policy and Practice. London: Edward Elgare Publishing, 2012.
17 Taylor N. Urban Planning Theory since 1945. London: SAGE Publications Ltd.; 1998.
18 Stevenson M, Thompson J, de Sá TH, et al. Land use, transport, and population health: estimating the health benefits of compact cities. *Lancet* 2016; published online Sept 23. http://dx.doi.org/10.1016/S0140-6736(16)30067-8.
19 Sallis J, Bull F, Burdett R, et al. Using science to guide city planning policy and practice to promote health. *Lancet* 2016; published online Sept 23. http://dx.doi.org/10.1016/S0140-6736(16)30068-X.
20 Ewing R, Cervero R. Travel and the built environment: a meta-analysis. *J Am Plann Assoc* 2010; **76:** 265–94.
21 World Health Organization. UN-Habitat. Hidden cities: unmasking and overcoming health inequities in urban settings. Geneva: World Health Organization, 2010.
22 Macintyre S, Ellaway A. Neighborhoods and health: an overview. In: Kawachi I, Berkman L, editors. Neighbourhoods and health. Oxford, UK: Oxford University Press, 2003: p. 20-42.
23 Diez Roux AV, Mair C. Neighborhoods and health. *Ann N Y Acad Sci* 2010; **1186:** 125–45.
24 Turrell G, Kavanagh A, Draper G, Subramanian SV. Do places affect the probability of death in Australia? A multilevel study of area-level disadvantage, individual-level socioeconomic position and all-cause mortality, 1998-2000. *J Epidemiol Community Health* 2007; **61:** 13–19.
25 Mohan D. Road safety in less-motorized environments: future concerns. *Int J Epidemiol* 2002; **31:** 527–32.
26 Peden M, Scurfield R, Sleet D, et al, World report on road traffic injury prevention. Geneva: World Health Organization and World Bank, 2004.
27 Burch C, Cook L, Dischinger P. A comparison of KABCO and AIS injury severity metrics using CODES linked data. *Traffic Inj Prev* 2014; **15:** 627–30.
28 World Health Organization. Health statistics and information systems. Estimates for 2000–2012. 2015. http://www.who.int/healthinfo/global_burden_disease/estimates/en/index2.html (accessed May 17, 2016).
29 Bhalla K, Shotten M, Cohen A, et al. Transport for health: the global burden of disease from motorized road transport. Washington, DC: World Bank Group, 2014.
30 Mathers CD, Fat DM, Inoue M, Rao C, Lopez AD. Counting the dead and what they died from: an assessment of the global status of cause of death data. *Bull World Health Organ* 2005; **83:** 171–77.
31 Yeo J, Park S, Jang K. Effects of urban sprawl and vehicle miles traveled on traffic fatalities. *Traffic Inj Prev* 2015; **16:** 397–403.
32 Malekafzali S. Healthy, equitable transportation policy: recommendations and research. Oakland, CA: Prevention Institute, 2009.
33 Bhalla K, Ezzati M, Mahal A, Salomon J, Reich M. A risk-based method for modeling traffic fatalities. *Risk Anal* 2007; **27:** 125–36.
34 World Health Organization. Global status report on road safety. Geneva: World Health Organization, 2013.

35 Fuller D, Morency P. A population approach to transportation planning: reducing exposure to motor-vehicles. *J Environ Public Health* 2013; **2013:** 916460.

36 International Traffic Safety Data and Analysis Group. Road safety annual report 2014: summary. Paris, France: International Transport Forum, OECD, 2014.

37 Campbell B, Zegeer C, Huang H, Cynecki M. A review of pedestrian safety research in the United States and abroad. Washington, DC: Federal Highway Administration, 2004.

38 US Department of Transportation. Traffic safety facts 2012 data: pedestrians. 2014. http://www-nrd.nhtsa.dot.gov/Pubs/811888.pdf (accessed May 21, 2015).

39 Giles-Corti B, Kelty SF, Zubrick SR, Villanueva KP. Encouraging walking for transport and physical activity in children and adolescents: how important is the built environment? *Sports Med* 2009; **39:** 995–1009.

40 Shaw B, Watson B, Frauendienst B, Redecker A, Jones T, Hillman M. Children's independent mobility: a comparative study in England and Germany (1971-2010). London: Policy Studies Institute, 2013.

41 Fyhri A, Hjorthol R, Mackett RL, Fotel TN, Kytta M. Children's active travel and independent mobility in four countries: development, social contributing trends and measures. *Transp Policy* 2011; **18:** 703–10.

42 Buehler R, Pucher J. Walking and cycling in Western Europe and the United States: trends, policies, and lessons. *TR News* 2012; **5:** 34–42.

43 Pucher J, Dijkstra L. Promoting safe walking and cycling to improve public health: lessons from The Netherlands and Germany. *Am J Public Health* 2003; **93:** 1509–16.

44 Pucher J, Dill J, Handy S. Infrastructure, programs, and policies to increase bicycling: an international review. *Prev Med* 2010; **50** (suppl 1): S106–25.

45 World Health Organization. More than 270 000 pedestrians killed on roads each year. 2013. http://www.who.int/mediacentre/news/notes/2013/make_walking_safe_20130502/en/ (accessed June 12, 2015).

46 Gasana J, Dillikar D, Mendy A, Forno E, Ramos Vieira E. Motor vehicle air pollution and asthma in children: a meta-analysis. *Environ Res* 2012; **117:** 36–45.

47 Yang W, Omaye ST. Air pollutants, oxidative stress and human health. *Mutat Res* 2009; **674:** 45–54.

48 Samet J, Krewski D. Health effects associated with exposure to ambient air pollution. *J Toxicol Environ Health A* 2007; **70:** 227–42.

49 Shah ASV, Langrish JP, Nair H, et al. Global association of air pollution and heart failure: a systematic review and meta-analysis. *Lancet* 2013; **382:** 1039–48.

50 Lim SS, Vos T, Flaxman AD, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; **380:** 2224–60.

51 Samet J. Community design and air quality. In: Dannenberg A, Frumkin H, Jackson R, editors. Making healthy places: Designing and building for health, wellbeing, and sustainability. Washington, DC: Island Press, 2011.

52 Cervero R. Linking urban transport and land use in developing countries. *J Transport Land Use* 2013; **6:** 7–24.

53 Zhu Y, Hinds WC, Kim S, Sioutas C. Concentration and size distribution of ultrafine particles near a major highway. *J Air Waste Manag Assoc* 2002; **52:** 1032–42.

54 Gwilliam K. Urban transport in developing countries. *Transp Rev* 2003; **23:** 197–216.

55 Woodcock J, Edwards P, Tonne C, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. *Lancet* 2009; **374:** 1930–43.

56 Giles LV, Koehle MS. The health effects of exercising in air pollution. *Sports Med* 2014; **44:** 223–49.

57 Rank J, Folke J, Jespersen PH. Differences in cyclists and car drivers exposure to air pollution from traffic in the city of Copenhagen. *Sci Total Environ* 2001; **279:** 131–36.

58 Kent J, Thompson S. Connecting and strengthening communities in places for health and well-being. *Australian Planner* 2014; **51:** 260–71.

59 Rojas-Rueda D, de Nazelle A, Tainio M, Nieuwenhuijsen MJ. The health risks and benefits of cycling in urban environments compared with car use: health impact assessment study. *BMJ* 2011; **343:** d4521.

60 Johan de Hartog J, Boogaard H, Nijland H, Hoek G. Do the health benefits of cycling outweigh the risks? *Environ Health Perspect* 2010; **118:** 1109–16.

61 Giles-Corti B, Ryan K, Foster S. Increasing density in Australia: Maximising the health benefits and minimising harm. Melbourne: National Heart Foundation of Australia, 2012.

62 Ising H, Kruppa B. Health effects caused by noise: evidence in the literature from the past 25 years. *Noise Health* 2004; **6:** 5–13.

63 Tobías A, Recio A, Díaz J, Linares C. Health impact assessment of traffic noise in Madrid (Spain). *Environ Res* 2015; **137:** 136–40.

64 Moudon AV. Real noise from the urban environment: how ambient community noise affects health and what can be done about it. *Am J Prev Med* 2009; **37:** 167–71.

65 Hänninen O, Knol AB, Jantunen M, et al, and the EBoDE Working Group. Environmental burden of disease in Europe: assessing nine risk factors in six countries. *Environ Health Perspect* 2014; **122:** 439–46.

66 Clark C, Stansfeld SA. The effect of transportation noise on health and cognitive development: a review of recent evidence. *Int J Comp Psychol* 2007; **20:** 145–58.

67 van Kempen EEMM, Kruize H, Boshuizen HC, Ameling CB, Staatsen BAM, de Hollander AEM. The association between noise exposure and blood pressure and ischemic heart disease: a meta-analysis. *Environ Health Perspect* 2002; **110:** 307–17.

68 Babisch W. Road traffic noise and cardiovascular risk. *Noise Health* 2008; **10:** 27–33.

69 Evans GW. The built environment and mental health. *J Urban Health* 2003; **80:** 536–55.

70 Halpern D. Mental health and the build environment: more than bricks and mortar? Bristol: Taylor and Francis, 1995.

71 Holt-Lunstad J, Smith TB, Baker M, Harris T, Stephenson D. Loneliness and social isolation as risk factors for mortality: a meta-analytic review. *Perspect Psychol Sci* 2015; **10:** 227–37.

72 Hale C. Fear of crime: a review of the literature. *Int Rev Victimology* 1996; **4:** 79–150.

73 Foster S, Giles-Corti B. The built environment, neighborhood crime and constrained physical activity: an exploration of inconsistent findings. *Prev Med* 2008; **47:** 241–51.

74 Carver A, Timperio A, Crawford D. Playing it safe: the influence of neighbourhood safety on children's physical activity. A review. *Health Place* 2008; **14:** 217–27.

75 Lovasi GS, Hutson MA, Guerra M, Neckerman KM. Built environments and obesity in disadvantaged populations. *Epidemiol Rev* 2009; **31:** 7–20.

76 Lorenc T, Clayton S, Neary D, et al. Crime, fear of crime, environment, and mental health and wellbeing: mapping review of theories and causal pathways. *Health Place* 2012; **18:** 757–65.

77 Cozens P. New urbanism, crime and the suburbs: a review of the evidence. *Urban Policy Res* 2008; **26:** 429–44.

78 Day K. Strangers in the night: women's fear of sexual assault on urban college campuses. *J Archit Plann Res* 1999; **16:** 289–312.

79 World Health Organization. Global status report on non-communicable diseases 2014. Geneva: World Health Organization, 2015.

80 Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, and the Lancet Physical Activity Series Working Group. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet* 2012; **380:** 219–29.

81 Van Holle V, Deforche B, Van Cauwenberg J, et al. Relationship between the physical environment and different domains of physical activity in European adults: a systematic review. *BMC Public Health* 2012; **12:** 807.

82 Hajna S, Ross NA, Brazeau AS, Bélisle P, Joseph L, Dasgupta K. Associations between neighbourhood walkability and daily steps in adults: a systematic review and meta-analysis. *BMC Public Health* 2015; **15:** 768.

83 McCormack GR, Shiell A. In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. *Int J Behav Nutr Phys Act* 2011; **8:** 125.

84 Saelens BE, Sallis JF, Frank LD, et al. Neighborhood environment and psychosocial correlates of adults' physical activity. *Med Sci Sports Exerc* 2012; **44:** 637–46.

85 Sugiyama T, Neuhaus M, Cole R, Giles-Corti B, Owen N. Destination and route attributes associated with adults' walking: a review. *Med Sci Sports Exerc* 2012; **44:** 1275–86.

86 Sugiyama T, Leslie E, Giles-Corti B, Owen N. Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? *J Epidemiol Community Health* 2008; **62:** e9.

87 Francis J, Wood LJ, Knuiman M, Giles-Corti B. Quality or quantity? Exploring the relationship between Public Open Space attributes and mental health in Perth, Western Australia. *Soc Sci Med* 2012; **74:** 1570–77.

88 Maller C, Townsend M, Brown P, St Leger L. Healthy parks healthy people. The health benefits of contact with nature in a park context. Melbourne: Deakin University, 2002.

89 Roe JJ, Thompson CW, Aspinall PA, et al. Green space and stress: evidence from cortisol measures in deprived urban communities. *Int J Environ Res Public Health* 2013; **10:** 4086–103.

90 Takano T, Nakamura K, Watanabe M. Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *J Epidemiol Community Health* 2002; **56:** 913–18.

91 Owen N. Sedentary behavior: understanding and influencing adults' prolonged sitting time. *Prev Med* 2012; **55:** 535–39.

92 Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: the population health science of sedentary behavior. *Exerc Sport Sci Rev* 2010; **38:** 105–13.

93 Dunstan DW, Barr EL, Healy GN, et al. Television viewing time and mortality: the Australian Diabetes, Obesity and Lifestyle study (AusDiab). *Circulation* 2010; **121:** 384–91.

94 Thorp AA, Owen N, Neuhaus M, Dunstan DW. Sedentary behaviors and subsequent health outcomes in adults a systematic review of longitudinal studies, 1996-2011. *Am J Prev Med* 2011; **41:** 207–15.

95 Healy GN, Dunstan DW, Salmon J, Shaw JE, Zimmet PZ, Owen N. Television time and continuous metabolic risk in physically active adults. *Med Sci Sports Exerc* 2008; **40:** 639–45.

96 Owen N, Sparling PB, Healy GN, Dunstan DW, Matthews CE. Sedentary behavior: emerging evidence for a new health risk. *Mayo Clin Proc* 2010; **85:** 1138–41.

97 Sugiyama T, Ding D, Owen N. Commuting by car: weight gain among physically active adults. *Am J Prev Med* 2013; **44:** 169–73.

98 Sugiyama T, Neuhaus M, Owen N. Active transport, the built environment and human health. In: Rassia S, Pardalos P, editors. Sustainable environmental design in architecture: impacts on health. London: Springer, 2011: 43–67.

99 Vallance JK, Winkler EA, Gardiner PA, Healy GN, Lynch BM, Owen N. Associations of objectively-assessed physical activity and sedentary time with depression: NHANES (2005-2006). *Prev Med* 2011; **53:** 284–88.

100 Kazi A, Duncan M, Clemes S, Haslam C. A survey of sitting time among UK employees. *Occup Med (Lond)* 2014; **64:** 497–502.

101 Ng SW, Popkin BM. Time use and physical activity: a shift away from movement across the globe. *Obes Rev* 2012; **13:** 659–80.

102 Owen N, Salmon J, Koohsari MJ, Turrell G, Giles-Corti B. Sedentary behaviour and health: mapping environmental and social contexts to underpin chronic disease prevention. *Br J Sports Med* 2014; **48:** 174–77.

103 Owen N, Sugiyama T, Eakin EE, Gardiner PA, Tremblay MS, Sallis JF. Adults' sedentary behavior determinants and interventions. *Am J Prev Med* 2011; **41:** 189–96.

104 Koohsari MJ, Sugiyama T, Sahlqvist S, Mavoa S, Hadgraft N, Owen N. Neighborhood environmental attributes and adults' sedentary behaviors: Review and research agenda. *Prev Med* 2015; **77:** 141–49.

105 Lock K, Pomerleau J, Causer L, Altmann DR, McKee M. The global burden of disease attributable to low consumption of fruit and vegetables: implications for the global strategy on diet. *Bull World Health Organ* 2005; **83:** 100–08.

106 Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014; **384:** 766–81.

107 Caspi CE, Sorensen G, Subramanian SV, Kawachi I. The local food environment and diet: a systematic review. *Health Place* 2012; **18:** 1172–87.

108 Thornton LE, Pearce JR, Macdonald L, Lamb KE, Ellaway A. Does the choice of neighbourhood supermarket access measure influence associations with individual-level fruit and vegetable consumption? A case study from Glasgow. *Int J Health Geogr* 2012; **11:** 29.

109 Thornton LE, Pearce JR, Kavanagh AM. Using Geographic Information Systems (GIS) to assess the role of the built environment in influencing obesity: a glossary. *Int J Behav Nutr Phys Act* 2011; **8:** 71.

110 Boone-Heinonen J, Gordon-Larsen P, Kiefe CI, Shikany JM, Lewis CE, Popkin BM. Fast food restaurants and food stores: longitudinal associations with diet in young to middle-aged adults: the CARDIA study. *Arch Intern Med* 2011; **171:** 1162–70.

111 Fan J, Hanson H, Zick C, Brown B, Kowaleski-Jones L, Smith K. Geographic scale matters in detecting the relationship between neighborhood food environments and obesity risk: an analysis of driver license records. *BMJ Open* 2014; **4**: e005458.

112 Miura K, Turrell G. Contribution of psychosocial factors to the association between socioeconomic position and takeaway food consumption. *PLoS ONE* 2014; **9:** e108799.

113 Michimi A, Wimberly MC. Associations of supermarket accessibility with obesity and fruit and vegetable consumption in the conterminous United States. *Int J Health Geogr* 2010; **9:** 49.

114 Coveney J, O'Dwyer LA. Effects of mobility and location on food access. *Health Place* 2009; **15:** 45–55.

115 Winkler E, Turrell G, Patterson C. Does living in a disadvantaged area mean fewer opportunities to purchase fresh fruit and vegetables in the area? Findings from the Brisbane food study. *Health Place* 2006; **12:** 306–19.

116 Popkin BM, Adair LS, Ng SW. Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev* 2012; **70:** 3–21.

117 Godfray HC, Beddington JR, Crute IR, et al. Food security: the challenge of feeding 9 billion people. *Science* 2010; **327:** 812–18.

118 United Nations Department of Economic and Social Affairs Population Division. World urbanization prospects: the 2011 revision. Data tables and highlights. New York, NY, USA: United Nations; 2012.

119 Knox P, McCarthy L. Urbanization: an introduction to urban geography. 3rd ed. Boston, MA, USA: Pearson; 2012.

120 Gomez LF, Sarmiento R, Ordoñez MF, et al. Urban environment interventions linked to the promotion of physical activity: a mixed methods study applied to the urban context of Latin America. *Soc Sci Med* 2015; **131:** 18–30.

121 Cervero R, Golub A. Informal transport: a global perspective. *Transp Policy* 2007; **14:** 445–57.

122 United Nations Human Settlements Programme. Planning and design for sustainable urban mobility: policy directions: global report on human settlements 2013. Abridged edition. Abingdon, Oxon: Routledge, 2013.

123 Vlahov D. Urban health: global perspectives. 1st ed. San Francisco, CA: Jossey-Bass, 2010.

124 World Bank. World development indicators 2011 on CD-ROM. Washington, DC: World Bank, 2011.

125 World Health Organization. Healthy urban planning: Report of a consultation meeting. Kobe, Japan: Centre for Health Development, World Health Organization, 2011.

126 Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U, and the Lancet Physical Activity Series Working Group. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet* 2012; **380:** 247–57.

127 Satterthwaite D. The links between poverty and the environment in urban areas of Africa, Asia, and Latin America. *Ann Am Acad Pol Soc Sci* 2003; **590:** 73–92.

128 Ji S, Cherry CR, J Bechle M, Wu Y, Marshall JD. Electric vehicles in China: emissions and health impacts. *Environ Sci Technol* 2012; **46:** 2018–24.

129 Bell AC, Ge K, Popkin BM. The road to obesity or the path to prevention: motorized transportation and obesity in China. *Obes Res* 2002; **10:** 277–83.

130 Harpham T, Tanner M. Urban health in developing countries: progress and prospects. Oxon: Earthscan, 2013.

131 Díaz Del Castillo A, Sarmiento OL, Reis RS, Brownson RC. Translating evidence to policy: urban interventions and physical activity promotion in Bogotá, Colombia and Curitiba, Brazil. *Transl Behav Med* 2011; **1:** 350–60.

132 Hidalgo DGL. BRT and BHLS around the world: explosive growth, large positive impacts and many issues outstanding. *Res Transp Econ* 2013; **39:** 8–13.

133 Hino AA, Reis RS, Sarmiento OL, Parra DC, Brownson RC. Built environment and physical activity for transportation in adults from Curitiba, Brazil. *J Urban Health* 2014; **91:** 446–62.

134 Sarmiento OL, Schmid TL, Parra DC, et al. Quality of life, physical activity, and built environment characteristics among colombian adults. *J Phys Act Health* 2010; **7** (suppl 2)**:** S181–95.

135 United Nations Human Settlements Programme. State of Latin American and Caribbean cities 2012. Towards a new urban transition. Kenya: UN-Habitat, 2012.

136 Shaheen S, Zhang H, Martin E, Guzman S. China's Hangzhou public bicycle: understanding early adoption and behavioral response to bikesharing. *Transp Res Rec* 2011; **2247:** 33–41.

137 Tang Y, Pan H, Shen Q. Bike-renting systems in Beijing, Shanghai and Hangzhou and their impact on travel behavior. Paper 11-3862. Transportation Research Board 90th Annual Meeting; 2011; Washington, DC: Transportation Research Board, 2011.

138 Dobbs R, Pohl H, Lin D-Y, et al. Infrastructure productivity: how to save $1 trillion a year. London: McKinsey Global Institute, 2013.

139 Haines A, McMichael AJ, Smith KR, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers. *Lancet* 2009; **374:** 2104–14.

140 Giles-Corti B, Foster S, Shilton T, Falconer R. The co-benefits for health of investing in active transportation. *N S W Public Health Bull* 2010; **21:** 122–27.

141 Marmot M, Allen J, Goldblatt P, et al. Fair society, healthy lives: the Marmot Review. Strategic review of health inequalities in England post-2010. London: UCL Institute for Health Equity, 2010.

142 Putnam R. Bowling alone: the collapse and revival of American community. New York, NY: Simon & Schuster, 2000.

143 Lowe M. Obesity and climate change mitigation in Australia: overview and analysis of policies with co-benefits. *Aust N Z J Public Health* 2014; **38:** 19–24.

144 World Health Organization. Can urban development, housing and transport policy act as health policy? Economics of social determinants of health and health inequalities: a resource book: World Health Organization, 2013: 93–114.

145 Hooper P, Giles-Corti B, Knuiman M. Evaluating the implementation and active living impacts of a state government planning policy designed to create walkable neighborhoods in Perth, Western Australia. *Am J Health Promot* 2014; **28** (suppl)**:** S5–18.

146 Schweizer C, Racioppi F, Nemer L. Developing national action plans on transport, health and environment: A step-by-step manual for policy-makers and planners. Copenhagen: WHO Regional Office for Europe, 2014.

147 Giles-Corti B, Sallis JF, Sugiyama T, Frank LD, Lowe M, Owen N. Translating active living research into policy and practice: one important pathway to chronic disease prevention. *J Public Health Policy* 2015; **36:** 231–43.

148 World Health Organization. The Ottawa Charter for health promotion. *Health Promot Int* 1986; **1:** 3–5.

149 Turrell G, Haynes M, Wilson LA, Giles-Corti B. Can the built environment reduce health inequalities? A study of neighbourhood socioeconomic disadvantage and walking for transport. *Health Place* 2013; **19:** 89–98.

150 Sustainable Development Commission. Fairness in a car-dependent society. London, UK: Sustainable Development Commission; 2011.

151 Lipfert FW. Air pollution and poverty: does the sword cut both ways? *J Epidemiol Community Health* 2004; **58:** 2–3.

152 World Health Organization. Urban HEART: Urban Health Equity Assessment and Response Tool: user manual. Kobe, Japan: WHO Centre for Health Development, 2010.

153 Craig P, Cooper C, Gunnell D, et al. Using natural experiments to evaluate population health interventions: new Medical Research Council guidance. *J Epidemiol Community Health* 2012; **66:** 1182–86.

154 Bates CJ, Hamer M, Mishra GD. A study of relationships between bone-related vitamins and minerals, related risk markers, and subsequent mortality in older British people: the National Diet and Nutrition Survey of People Aged 65 Years and Over. *Osteoporos Int* 2012; **23:** 457–66.

155 Goodman A, Sahlqvist S, Ogilvie D, and the iConnect Consortium. New walking and cycling routes and increased physical activity: one- and 2-year findings from the UK iConnect Study. *Am J Public Health* 2014; **104:** e38–46.

156 Giles-Corti B, Knuiman M, Timperio A, et al. 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. *Prev Med* 2008; **46:** 46–54.