Chapter 20
Green Space and Health

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20.1 Overview

During the last century, the world experienced a rapid urbanization which is still ongoing in different parts of the world. Nowadays, more than half of the global population lives in cities and this proportion is projected to rise to two-third by 2050 (UN Department of Economic and Social Affairs 2015). Cities are recognized as the powerhouses of innovation and wealth creation where people usually have better access to healthcare (Bettencourt et al. 2007). However, urban areas are often associated with higher levels of a number of environmental hazards such as air pollution, noise, and heat and limited access to nature, including green spaces. At the same time, urban lifestyle is predominantly associated with lower levels of physical activity and higher exposure to crime and psychological stress (Bettencourt et al. 2007). These environmental and lifestyle factors could contribute to the existing higher prevalence of a wide range of adverse health conditions such as psychological disorders and non-communicable diseases in urban areas (Cyril et al. 2013). Natural environments, including green spaces, have been associated with improved mental and physical health and well-being and are increasingly recognized as a mitigation measure to buffer the aforementioned adverse health effects of urban living. This chapter provides an overview of (1) urban green spaces, (2) the methods that are applied to characterize exposure to these spaces, (3) the potential mechanisms through which green spaces could exert their health effects, (4) the health effects associated with contact to green spaces, and (5) the role of socioeconomic status (SES) in such effects.

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20.2 Urban Green Spaces

The US Environmental Protection Agency (EPA) defines green spaces as the *land that is partly or completely covered with grass, trees, shrubs, or other vegetation* which includes *parks, community gardens, and cemeteries* (US Environmental Protection Agency 2017). The abundance and availability of green spaces in urban areas could be a function of several factors from which the climate and urban planning play key roles. For example, a survey of 386 European cities (2009) revealed that while there was a general north-south decreasing gradient in the percentage of green space coverage within these cities, still there were greener cities in south and less green cities in north (Fuller and Gaston 2009). The amount of green space available to people in cities also varies considerably from, for example, 1.9 m^2 per person in Buenos Aires, Argentina to 52.0 m^2 in Curitiba, Brazil. There are many types of green in cities including parks, street green, and natural green which can be captured by different maps or remote sensing methods (Gascon et al. 2016a).

20.3 Characterization of Contact with Green Spaces

The methods to assess contact to green spaces are currently evolving. Different methods have been developed to characterize the following different aspects of such contact:

1. *Surrounding greenness*: A major part of the available evidence on health effects of green spaces has relied on characterization of greenness surrounding home addresses, and to less extent surrounding school or workplace, as an indicator of general greenness at living environment of the study subjects. These studies have either relied on (a) remote sensing-based indices of greenness (e.g. Normalized Vegetation Difference Index (NDVI)) to quantify the amount of photosynthetically active vegetation in a certain buffer around or within boundaries of home, school, or workplace or (b) available land-cover maps to abstract the percentage of green land covers in a certain buffer around the aforementioned places.
2. *Physical access to green spaces*: Proximity to green spaces has often been used as an indicator of access to these spaces. There are two approaches to characterize proximity to green spaces: (a) objective proximity to green spaces based on quantifying the distance (either Euclidian or network distance through available road network) between the address of interest and the closest green space with whatever size or those larger than a certain size. These studies have used distance as either a continuous variable or have dichotomize them using certain cut-offs. For example, some studies have applied the European Commission's recommendation for access to open spaces (including green spaces) defined as living within 300 m of an open/green space with a minimum area of 5000 m^2 (WHO Regional Office for Europe 2016). To date, a few studies (e.g. Dadvand et al. (2016)) have used (b) subjective proximity to green spaces to characterize access to green

spaces, by asking study subjects whether they have green spaces within a certain distance (e.g. 15-min walk) from their homes.

3. *Visual access to green spaces*: To date, few epidemiological studies have evaluated health effects of visual access to green spaces. These studies have applied either questionnaires asking study subjects about the proportion of green view through their window(s) or have rated the green view in the photos taken by study subjects or fieldworkers from the windows of interest.
4. *Use of green spaces*: Two approaches have been applied by the studies of health effects of green spaces to characterize use of green spaces: (a) questionnaires asking participants to report the time that they have spent and the type of physical activity they have conducted in green spaces over a certain period of time and (b) Global Positioning System (GPS) or smartphones to objectively measure the time that study subjects spend in different microenvironments including green spaces.
5. *Quality of green spaces*: Quality characteristics of green spaces such as aesthetics, biodiversity, walkability, sport/play facilities, safety, and organized social events have been suggested to predict the use of green spaces (McCormack et al. 2010); however, so far, most studies evaluating health effects of green spaces have overlooked these characteristics. Quality of green spaces has been often characterized based on systematic observation (audits) of these spaces by fieldworkers/study participants using tools developed for this aim (e.g. Van Dillen et al. (2012)). Recently, there has been a limited effort to use remote sensing images (e.g. Google Earth Pro (Taylor et al. 2011)) to characterize quality of green spaces which showed a strong correlation with the assessments made by in-person audits.

20.4 Potential Underlying Mechanism

The mechanism underlying health effects of green spaces is yet to be established, but stress reduction/cognitive restoration; mitigation of the exposure to air pollution, noise, and heat; enhancing social cohesion/interactions; increasing physical activity; and enriching micro- and macro-biodiversity and environmental microbial input have been suggested to be involved.

20.4.1 Stress Reduction/Cognitive Restoration

A substantial body of experimental and observational evidence has consistently showed the capability of green spaces in reducing stress and restoring cognition function. The *stress reduction theory* suggests that green spaces, through properties such as spatial openness, curving sightlines, and the presence of water, induce recovery from stress and help to diminish states of arousal and negative thoughts through psychophysiological pathways (Ulrich 1984). *Attention restoration theory* proposes that contact with nature with its inherently delightful stimuli could modestly invoke indirect (i.e. effortless) attention and in time minimize the need for directed attention that together could restore the directed attention mechanisms (Kaplan and Kaplan 1989; Kaplan 1995; Berman et al. 2008). These pathways have been indicated to play important roles in the health benefits of green spaces (de Vries et al. 2013; Dadvand et al. 2016).

20.4.2 Mitigating Environmental Exposures

The impact of green spaces on air pollution is complex and context-specific. On one hand, vegetations have been proposed to reduce air pollution by direct and indirect mechanisms (Givoni 1991). The direct mechanism is via filtering of air pollution by vegetations, principally based on dry deposition of pollutants (both particles and gases) through stomata uptake or non-stomata deposition on plant surfaces (Paoletti et al. 2011; Givoni 1991; Akbari 2002; Nowak et al. 2006). The indirect effect is mediated through cooling effects of plants that in turn reduces smog formation (Givoni 1991). A study on the effects of greenness surrounding residential address on personal exposure to air pollution using personal air pollution monitors reported that higher residential surrounding greenness was associated with reduced personal exposure to particulate air pollution but not nitric oxides (Dadvand et al. 2012c). Another study also showed that higher greenness within and surrounding schools is associated with lower indoor and outdoor levels of traffic-related air pollutants at school (Dadvand et al. 2015b). The ability of vegetations to reduce air pollution is thought to be type-specific with trees being the most efficient and grasses being the least efficient types (Givoni 1991). Studies on the capacity of canopies to remove air pollution in continental USA (Nowak et al. 2006) and Greater London (Tallis et al. 2011) estimated that about 1–2% of air pollution in these areas is removed by canopies. Experimental studies on mitigation effects of roadside vegetation on air pollution have reported inconsistent results with some reports that do not support such an effect (Baldauf et al. 2011; Hagler et al. 2012). Simulation studies of such effects have also indicated that roadside trees are able to generate a canyon effect with higher air pollution levels on the downwind and lower air pollution levels on the upwind side of the street (Buccolieri et al. 2009; Baldauf et al. 2011). Moreover, biodegradation of vegetation residues generates volatile organic compounds (VOCs), a family of air pollutants with potential health effects on humans. VOCs can also engage in complex photo chemical reactions with other air pollutants such as ozone and nitric oxides and participate in generation of biogenic secondary organic aerosols (Kesselmeier and Staudt 1999; Hoyle et al. 2011). Although the interaction between green spaces and air pollution appears to be multifaceted and complex and the available evidence on such interaction is still limited and inconsistent, the available studies evaluating the mediator role of air pollution in the observed health benefits of green spaces are suggestive for such a mediation. For example, a recent study of the effects of green spaces on cognitive development estimated that up to 60% of these effects could be explained by the reduction of traffic-related air pollutants by green spaces (Dadvand et al. 2015a).

The effect of green spaces on reducing temperature is well established. Evapotranspiration (release of water vapour into atmosphere), shading, and micro-regulating air movements and heat exchange are among the mechanisms through which vegetations could ameliorate the temperature (Bowler et al. 2010). A systematic review and meta-analysis of the available literature on such effect concluded that the temperature in urban parks is on average 1 °C less than that of other nongreen areas in the city (Bowler et al. 2010). Given the existence of heat island effect in urban areas, the capability of green spaces to reduce temperate is of importance for promoting resilience in cities, especially in the context of the occurring climate change.

The available evidence on mitigation of noise exposure by green spaces is still limited. However, these studies are suggestive for the buffering of the noise exposure/reduction of noise annoyance by residential surrounding greenness and green facades (De Ridder et al. 2004; Gidlöf-Gunnarsson and Öhrström 2007).

20.4.3 Enhancing Social Cohesion/Interaction

A cohesive society is defined as a society that *works towards the well-being of all its members, fights exclusion and marginalisation, creates a sense of belonging, promotes trust, and offers its members the opportunity of upward mobility* (Organization for Economic Cooperation and Development (OECD) 2011). Social cohesion/interaction have been associated with improved perceived general health (Kawachi et al. 2008), lower morbidity, more longevity, and reduced inequality in health (Marmot et al. 2012). The body of evidence on the association between contact with green spaces and social cohesion/interaction is still limited; however, it is generally supportive for such an association (Sugiyama et al. 2008; Maas et al. 2009a; de Vries et al. 2013; Dadvand et al. 2016), with a few exceptions (Triguero-Mas et al. 2015). Few studies have also shown the mediation of the association between green spaces and perceived general health by the improvement of social cohesion/interaction (Maas et al. 2009a; de Vries et al. 2013; Dadvand et al. 2016).

20.4.4 Increasing Physical Activity

Many of the studies have focused on physical activity as an important mechanism for the health of benefits. However, the available evidence on the impact of green spaces on physical activity is inconsistent with a considerable heterogeneity in the reported direction and strength of associations (Lachowycz and Jones 2011; McGrath et al. 2015) (Bancroft et al. 2015). A part of this inconsistency could be because of not accounting for the quality of green spaces in most of these studies, while these aspects are shown to affect the use of green spaces for physical activity (McCormack et al. 2010). The few studies evaluating the mediation of health benefits of green spaces by physical activity are also suggestive for a modest mediation role of physical activity in these benefits (de Vries et al. 2013; Dadvand et al. 2016).

20.4.5 Enriching Environmental Biodiversity

Plants are able to directly modulate the microbiome present in the rhizosphere (the below-ground microbial habitat provided by plant root systems) and phyllosphere (above-ground microbial habitats provided by plants) (Berendsen et al. 2012; Vorholt 2012) and therefore indirectly modulate the environmental microbiome to which humans are exposed. Studies have shown that bacterial diversity in humans' faeces decreases with the level of urbanization, which is strongly associated with reduced environmental biodiversity (De Filippo et al. 2010; Yatsunenko et al. 2012). Human microbiome including gut microbiome has been shown to interact with the host tissue, regulate systemic immune response, and prevent chronic inflammation (Martinez 2014). Therefore, the ability of urban green spaces to enhance immunoregulation-inducing microbial input from the environment (Rook 2013) could be a potential mechanism underlying the association between green spaces and human health. A study in adolescents, for example, showed that living near a forest increases the diversity of the skin microbiome which in turn was associated with reduced risk of allergic sensitization later in life (Hanski et al. 2012).

20.5 Health Benefits

Exposure to green spaces has been associated with improved physical and mental health and well-being. This exposure, for example, has been associated with improved perceived general health, better pregnancy outcomes (e.g. birth weight), enhanced brain development in children, better cognitive function in adults, improved mental health, lower risk of a number of chronic diseases (e.g. diabetes and cardiovascular conditions), and reduced premature mortality.

20.5.1 Pregnancy Outcomes

Higher greenness surrounding maternal residential address during pregnancy has been associated with increased birth weight in offspring (Dzhambov et al. 2014). The available evidence for such an association for the length of pregnancy is inconsistent. While some studies are suggestive for an increased length of gestation (i.e. reduced risk of preterm birth) associated with higher greenness surrounding maternal residential address (Laurent et al. 2013; Hystad et al. 2014; Grazuleviciene et al. 2015; Nichani et al. 2017), other studies have not supported this association (Dadvand et al. 2012a, b; Agay-Shay et al. 2014).

20.5.2 Brain Development

The "biophilia hypothesis" proposes evolutionary bonds of humans to nature (Wilson 1984; Kellert and Wilson 1993). Accordingly, contact with nature including green spaces is thought to have a crucial role in brain development in children (Kahn and Kellert 2002; Kellert 2005). Experimental studies have shown that playing in green spaces could reduce severity of symptoms and improve attention in children with attention deficit/hyperactivity disorder (ADHD) in short-term (Taylor et al. 2001; Kuo and Taylor 2004; Taylor and Kuo 2009; van den Berg and van den Berg 2011). Observational studies have revealed that higher residential surrounding greenness and more time spent playing in green spaces in the long run could reduce risk of behavioural and emotional problems including ADHD (Amoly et al. 2014; Markevych et al. 2014b) and enhance cognitive development including attention and working memory (Wells 2000; Dadvand et al. 2015a).

20.5.3 Cognitive Function

Exposure to green spaces has been associated with improved cognitive functions including better direct attentional capacity and lower concentration problems in adults (de Keijzer et al. 2016). The available evidence on the potential impact of this exposure in decelerating cognitive decline in elderly is still scarce and inconsistent (de Keijzer et al. 2016).

20.5.4 Perceived General Health

More contact with green spaces has been consistently associated with improved perceived general health (Gascon et al. 2015). Studies have shown that improved mental health and social cohesion and, to less extent, enhanced physical activity are among the main mechanisms underlying this association (de Vries et al. 2013; Dadvand et al. 2016).

20.5.5 Mental Health

The effect of green spaces on mental health is one of the most studied health effects of green spaces. More contact with green space has been associated with lower risk of psychological distress and psychiatric conditions such as depression and anxiety and less likelihood of use of psychiatric medicine (Gascon et al. 2015).

20.5.6 Other Non-communicable Diseases

The available evidence on the impacts of green spaces on non-communicable diseases other than asthma and allergy is still limited but is suggestive for a beneficial impact. More contact with green spaces has been associated with lower risk of cardiovascular conditions, diabetes, and low back pain (Maas et al. 2009b; Dalton et al. 2016). A recent study has also associated this contact with lower blood pressure in children (Markevych et al. 2014a).

20.5.7 Mortality

A recent systemic review and meta-analysis of the available literature on the impact of contact with green spaces on mortality have shown that higher residential surrounding greenness is associated with reduced all-cause premature mortality as well as cardiovascular mortality (Gascon et al. 2016b). Lower exposure to air pollution, higher physical activity, stronger perceived social engagement, and reduced risk of depression have been reported to mediate the association between exposure to green spaces and mortality (James et al. 2016).

20.6 Health Risks

Green spaces could potentially impose a number of health risks including increasing risk of asthma and allergic conditions, enhancing exposure to herbicides and pesticides, hosting reservoirs and vectors of infectious diseases, and increasing risk of accidental injuries.

20.6.1 Asthma and Allergy

The available evidence on the impact of green spaces on asthma and allergic conditions in children is inconsistent. While some studies have associated higher residential surrounding greenness with increased risk of asthma and allergic conditions (DellaValle et al. 2012; Lovasi et al. 2013; Andrusaityte et al. 2016), others have not shown such an association or have even shown protective effects (Lovasi et al. 2008; Maas et al. 2009b; Hanski et al. 2012; Pilat et al. 2012; Hind et al. 2017). The type of green space and the bioclimatic properties of the study region could explain, in part, such an inconsistency. One study, for example, has shown that while urban parks were associated with higher risk of asthma and allergic attacks, natural green spaces (e.g. forests) did not show such an association (Dadvand et al. 2014). Another study conducted in seven birth cohorts in Australia, Canada, Germany, Sweden, and the Netherlands showed a notable between-centre heterogeneity in terms of the direction and strength of associations (Fuertes et al. 2016).

20.6.2 Herbicide and Pesticide Exposure

Application of herbicides and pesticides in green spaces could expose individuals living in proximity of these spaces or those who use these spaces to these chemicals. Such an exposure could in turn lead to a range of health outcomes including cancers as well as adverse conditions in nervous, reproductive, endocrine, and immune systems (Blair et al. 2015).

20.6.3 Vector-Based and Zoonotic Infections

Green spaces could host vectors and reservoirs of infectious diseases, which could increase the risk of vector-borne diseases transferred by mosquitoes (e.g. malaria or dengue fever), ticks (e.g. Lyme disease and tick-borne encephalitis), or sandflies (e.g. leishmaniasis) (WHO Regional Office for Europe 2016). Exposure to animal faeces in green spaces can also result in zoonotic infections such as toxocariasis or toxoplasmosis (WHO Regional Office for Europe 2016).

20.6.4 Accidental Injuries

Users of green spaces, especially children, could experience accidental injuries such as falls or drowning while they are in these spaces. However, at population level, the injuries that occur in green spaces account for a very tiny proportion of accidental injuries (WHO Regional Office for Europe 2016).

20.7 Role of Socioeconomic Status

SES can be associated with both contact with greenness (e.g. high SES groups are more likely to live in greener neighbourhoods) and health status (e.g. high SES groups generally have better health status) making SES a potentially strong confounder of the analyses of the health benefits of green spaces. In addition to be a confounder, SES can also act as a modifier of the health effects of green spaces. Available studies are suggestive for greater benefits of green spaces for lower SES groups. This could be partly because groups with lower SES generally have poorer health status and live in areas with more environmental problems, and combination of these could make them more prone to benefit from health promotion interventions such as developing new green spaces (De Vries et al. 2003; Bolte et al. 2010; Su et al. 2011). Furthermore, lower SES groups are more likely to benefit from green spaces in proximity of their homes because they spend more time in the vicinity of their homes and availability of green spaces close to their homes can therefore increase the likelihood of their use of these spaces (Schwanen et al. 2002; Maas 2008). On the other hand, higher SES groups are more likely to use the green spaces farther away because of higher mobility (Greenspace Scotland 2008; Bell et al. 2010) and consequently their use of green spaces is less dependent on having green spaces close to their homes.

Given the greater benefits of green spaces for lower SES groups, these spaces have the potential to reduce inequality in health. A landmark study conducted in the entire England has showed that the income-related inequality in mortality is less evident in greener neighborhoods compared to less green neighborhoods (Mitchell and Popham 2008; Marmot 2010).

20.8 Green Space as a Pathway to Healthy Urban Living

Given the many benefits of green spaces, health of citizens in cities where there is a lack of green space can be improved by increasing the amount of green space (Nieuwenhuijsen et al. 2017; van den Bosch and Nieuwenhuijsen 2017). Cities can be made healthier and more equitable for people, not by painting trees on walls but by having a nearby park where people live, planting trees in the streets, and introducing urban gardens. Urban gardens may have additional benefits in terms of local food production and economy and, if done at a sufficiently large scale, can contribute to the sustainability and self-sufficiency of cities. Many cities need more parks, which can also become part of the identity and attraction of cities. Also, green roofs may transform the city, not only in terms of resilience but also in terms of visual attractiveness. Our current cites are too car dominated, and car infrastructures such as roads and parking lots take up much space that can be used for planting trees and other green. Reducing space for cars and the number of cars may have the additional advantage that people have to switch to public and active transportation and thereby reducing, e.g. air pollution, heat, and noise levels in cities and increasing physical activity in citizens (Nieuwenhuijsen and Khreis 2016). Although greening our cities is not the only solution to improving health of urban residents, it can certainly make an important contribution. Green cities, healthy people.

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