Epidemiology of green space and health: a walk in the park?

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The age-adjusted incidence of many non-communicable diseases (NCDs: allergies, asthma, autoimmune disease, some cancers, diabetes, neurodegenerative diseases, cardiovascular disease (CVD) and so on) is rising.[1] They are leading causes of hospitalisation and death and many have reached epidemic proportions, with marginalised populations most affected. Causes remain unclear and prevention options are thus often scant or not optimally effective. However, as increases have occurred in recent decades, environmental and lifestyle factors are probably central. Some risk factors are well studied (tobacco, air pollution, diet, physical activity) and clear associations with several NCDs are now established. Nonetheless, they do not account for all cases and often do not explain geographical and temporal trends, suggesting roles for other exposures.

One underexplored influence on NCDs is exposure to the natural environment. Since the pioneering work of Ulrich,[2] who found that surgical patients with a view overlooking a natural scene recovered more quickly, research has shown that exposure to the natural environment is associated with multiple beneficial outcomes, including lower mortality, higher birth weight, reduced risk of CVD and improved mental health.[3] It is also associated with reduced risk of: allergies, type II diabetes, stroke and cognitive decline, although results have not always been consistent.[3] We have recently shown, using linked data on nearly 50 000 infants followed for 18 years, that those growing up close to more green space were less likely to develop asthma.[4] Using a similar approach, we have shown reduced risks of attention deficit hyperactivity disorder[5] and childhood leukaemia.[6]

The idea that the natural environment provides health benefits is not new. For millennia, many people have believed that green space in built environments is healing and restorative. Vitruvius, a first century BC Roman architect wrote: 'The space in the middle, between the colonnades and open to the sky, ought to be embellished with green things; for walking in the open air is very healthy'.[7] Similar notions drove the development of 19th century city parks in London, Paris and New York. These parks—the 'lungs of the city'—were designed to ameliorate the adverse health effects of industrialisation.[8] Consistent with this and as early as 1839, writing about ways of reducing mortality associated with overcrowding in impoverished areas, William Farr, famed UK epidemiologist, noted that: '… and a park in the East end of London, would, probably, diminish the annual deaths by several thousands, prevent many years of sickness, and add several years to the lives of the entire population'.[9] As a result, the development of Victoria Park commenced in 1841 and was opened with little fanfare but great public enthusiasm in 1845.

Almost two centuries later, Nicholls *et al*, in this issue of the Journal,[10] provide empirical evidence to substantiate Farr's claim that neighbourhood green space reduces years of life lost (YLL). This cross-sectional nationwide linkage study from Scotland, involving people aged <65 years, showed that areas with more combined natural space (both green and blue) and private gardens were associated with reduced YLL; exposure to natural space also reduced disparity in YLL between high-deprivation and low-deprivation areas, a particular focus of Farr's work.

The use of YLL, combining the effects of poor health and premature death, is novel, with previous studies having focused on overall mortality or specific health outcomes. Although the authors note that they explored adjusting for urban/rural locality, they did not stratify on it, which would have provided reassurance that some of the observed effects were not, at least partially, due to urban/rural differences in: type and level of exposure to green space; level of deprivation; air pollution; access to healthcare and size of small-area statistical reporting units (potentially resulting in greater exposure misclassification for rural areas where units are considerably larger). As they acknowledge, it would have also been of interest to differentiate among types of green space, as not all green space is equally beneficial (see below). Despite these limitations, this study adds new evidence regarding the importance of exposure to green/blue space in maintaining good health (thus reducing YLL), while also adding further evidence that it may reduce health inequity. If this latter is true (previous results have been mixed), it could provide an additional public-health tool to reduce the large health inequities that exist for deprived populations, indigenous peoples and other ethnic minorities.

Why is green space beneficial? An obvious explanation is that interaction with the natural environment drove our evolution; thus, we prefer biologically diverse environments and derive mental benefits from them (the 'Biophilia Hypothesis').[11] Physical activity, facilitated by green space, is an established contributor to better health. Further, absorption by plants of air pollution may also reduce risk. Finally, the 'Biodiversity Hypothesis'[12] posits that reduced biodiversity (associated with lower neighbourhood green space) results in less diverse environmental and human microbiota; this, in turn, increases the risk of a range of conditions,[13] with commensal (eg, gastrointestinal, lung and skin) microbiota known to affect: (1) immunity and the maintenance of homeostasis and tolerance to environmental exposures, determined by, as yet, poorly defined early-life microbial–host interactions; (2) the nervous system via neurotransmitter-like compounds and (3) the endocrine system. Although the biodiversity hypothesis, alone, provides an explanation (and biological mechanisms) for the consistency of the findings across a wide spectrum of conditions, it is likely that associations are explained by a combination of all these hypotheses.

Substantial knowledge gaps remain, including limited understanding of what aspects of the natural environment are protective, which biological mechanisms are involved and how we can most effectively apply this knowledge to reduce the increasing burden of NCDs. This is not surprising because, despite the long-standing recognition of the importance of green space for health, the field is still in its infancy, with a recent systematic review[14] suggesting that only 11 articles on green space and health were published over the entire 20th century. Although the number of publications has increased steadily since 2000, peaking at

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2372 in 2018,[14] it is unlikely that these knowledge gaps will be fully addressed until we develop more refined exposure-assessment approaches—the greatest challenge for future research.

Currently, exposure assessment usually involves the use of the Normalised Difference Vegetation Index (NDVI), a greenness index derived from satellite imagery, land-use data or both. Although these give a measure of 'green things',[7] they provide, at best, a crude exposure index, with little ability to differentiate among vegetation types or among species/genera/families within the same vegetation type.[15] This is an important limitation as grass is unlikely to offer the same benefits as mature trees with the same NDVI value; similarly, monocultures are unlikely to provide the same benefit as equally green complex ecosystems (with associated diverse fauna and microbiota). We have established this in our aforementioned asthma study, which showed protective effects for New Zealand native vegetation, whereas neighbourhood exposure to exotic monoculture species (gorse, pine) increased asthma risk.[4] Although remote-sensing, including Light Detection and Ranging, combined with other measures of ecological diversity hold promise,[6 15] this is a complex (but not impossible) issue to resolve.

Thus, although the burgeoning field of green-space-and-health epidemiology has considerable potential to advance understanding of the connection between the natural environment and health, facilitating the development of effective public-health interventions (eg, by rewilding urban centres), substantial challenges remain—a walk in the park it is not.

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