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A Review of the Health Benefits of Greenness

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Abstract Researchers are increasingly exploring how neighborhood greenness, or vegetation, may affect health behaviors and outcomes. Greenness may influence health by promoting physical activity and social contact; decreasing stress; and mitigating air pollution, noise, and heat exposure. Greenness is generally measured using satellite-based vegetation indices or land-use databases linked to participants' addresses. In this review, we found fairly strong evidence for a positive association between greenness and physical activity and a less consistent negative association between greenness and body weight. Research suggests greenness is protective against adverse mental health outcomes, cardiovascular disease, and mortality, though most studies were limited by cross-sectional or ecological design. There is consistent evidence that greenness exposure during pregnancy is positively associated with birth weight, though findings for other birth outcomes are less conclusive. Future research should follow subjects prospectively, differentiate between greenness quantity and quality, and identify mediators and effect modifiers of greenness-health associations.

Keywords Body weight · Health benefits · Greenness · Physical activity

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Introduction

Across all cultures in the world, an inherent value is placed on nature. For the Japanese, forest bathing, or *Shinrin-yoku* [1], involves taking in the forest atmosphere to reduce stress. *Friluftsliv* is a Scandinavian philosophy based on spiritual connectedness with the landscape [2]. Even in large cities, real estate values are highest in proximity to natural, green spaces [3–5]. A growing body of empirical evidence has begun to demonstrate links between exposure to nature, specifically green vegetation, and an array of health outcomes. In this review, we explore the mechanisms by which surrounding greenness may affect health (Fig. 1), detail methods to measure greenness exposure, review and summarize the evidence on exposure to greenness and various health outcomes (Table 1), and suggest necessary next steps to advance research in this field. This review is not meant to be comprehensive, but results from a survey of recent public health literature. The details of each study we reviewed can be found in Supplemental Table S1.

Mechanisms for Nature's Effect on Health

A number of mechanisms for the positive effects of green and natural spaces on health have been suggested. The biologist E.O. Wilson developed the biophilia hypothesis, which

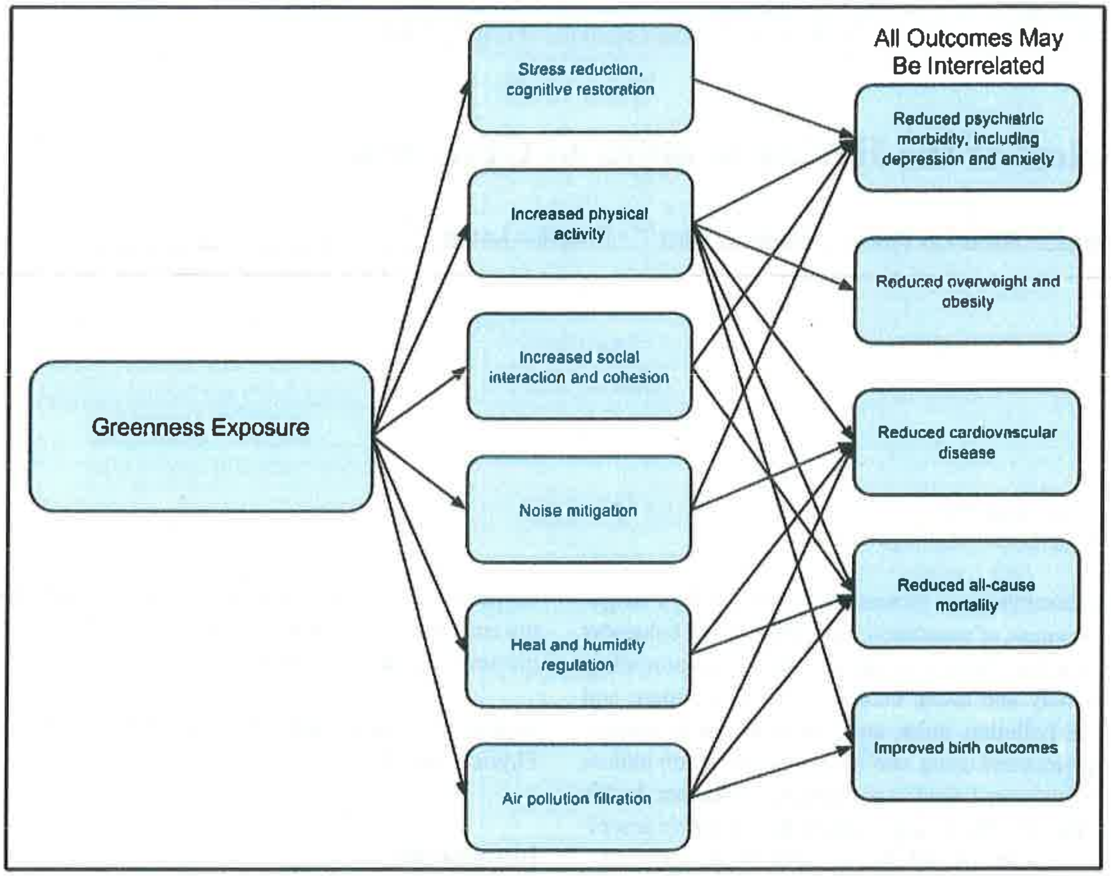

Fig. 1 Pathways through which greenness may affect health

suggests that human beings have evolved to have an affinity for nature, plants, and living things [6, 7]. Building on this, Ulrich's psychoevolutionary theory posits that exposure to nature may have a direct restorative effect on cognition and may decrease stress [8, 9]. Access to green spaces may also provide opportunities for social interactions and increase social cohesion. Higher levels of social cohesion, or the presence of strong social bonds, have been linked to multiple health outcomes [10]. Natural environments provide locations for both routine and recreational physical activity [11]. Vegetation may buffer exposure to air pollution, removing ozone, particulate matter, NO_2, SO_2, and carbon monoxide from the air [12]. Vegetation may also reduce exposure to harmful noise [13], as well as alleviate thermal discomfort during heat stress [14].

Exposure Assessment

Greenness and green space access have been quantified in epidemiologic studies predominantly using a vegetation index (typically the Normalized Difference Vegetation Index (NDVI)) or land-use databases. Vegetation indices, derived from satellite imagery, measure light reflected from the earth's surface during photosynthetic activity, from which vegetative density can be estimated [15]. Greenness is often defined as the mean NDVI value within a spatial area (e.g., census tract or radius around a participant's home). Studies that have employed land-use databases [16–18], which classify land units according to their predominant use, typically calculated the percent of a spatial area covered by parks, public gardens, sports fields, forests, or other green space types. A third, less common metric involved measuring the distance from a participant's residence to the nearest park, major green space, or public open space [19–21]. For an example of these metrics, please see Fig. 2. Finally, a small number of studies conducted environmental assessments [22•] or queried participants about the perceived greenness of their neighborhood [23].

Exposure metrics vary according to their spatial and temporal characteristics. Vegetation indices are available at a range of spatial and temporal resolutions. The commonly used NDVI can be downloaded at resolutions from 30 m–8 km for periods of 7 days to half a month [24]. Land-use datasets classify land uses at various resolutions. Depending on the source, spatial resolution can be fine (e.g., 30 m [25]) and land-use datasets are usually updated over years rather than months. For instance, the National Land Cover Dataset is updated every 5 years.

Table 1 Strength of evidence for greenness and health outcomes

Outcome	Study designs	Setting	Findings	Strength of evidence
Physical activity	15 cross-sectional studies [26•, 27, 28, 33-43, 45] 1 prospective study [44]	4 studies in the USA, 6 in the UK, 2 in France, 1 each in Australia, Netherlands, New Zealand, and Spain	Consistent evidence of positive association between greenness and physical activity. Few prospective studies.	I/II
Overweight/ obesity	10 cross-sectional studies [19, 43, 46-49, 51-54] 1 prospective study [50]	3 studies in the USA, 2 in the UK, 2 in Canada, 1 each in Australia, Denmark, Egypt, and Spain	Some evidence of negative association between greenness overweight/obesity, though findings (especially among children) were mixed. Possible effect modification by gender. Few prospective studies.	II
Mental health	11 cross-sectional studies [20, 22•, 23, 56, 58-61, 63-65] 3 prospective studies [57, 66, 67]	4 studies in the UK, 2 in Netherlands, 2 in the USA, 1 each in Australia, Canada, Denmark, New Zealand, Spain, and Sweden	Suggestive protective effect of greenness on self-reported mental health. More prospective studies needed.	II
Birth and developmental outcomes	6 birth cohort studies [31•, 68, 69, 71-73] 2 cross-sectional studies of allergies and asthma and hyperactivity [21, 32, 43].	2 studies in Spain, 2 studies in Germany, 1 each in Canada, France, Israel, and the UK	Consistent evidence of a positive relationship between residential greenness exposure and birth weight. Possible effect modification by SES. Findings for other birth and developmental outcomes require further evidence.	I/II
Cardiovascular outcomes	2 experimental studies [83. 84] 3 ecological studies [16, 78, 79] 3 cross-sectional studies [62, 80, 81] 1 prospective cohort study [82•]	4 studies in the UK, 1 each in the USA, Netherlands, Germany, Australia, and Canada	Consistent evidence of higher greenness and lower cardiovascular disease; however, most studies are ecological and cross-sectional. One prospective study could not account for individual-level smoking.	II/III
Mortality	3 prospective studies [82•, 85, 87] 5 ecological studies [16, 78, 79, 86, 88]	3 studies in the UK, 2 studies in the USA, 1 each in Japan, New Zealand, and Canada	Fairly consistent evidence of higher greenness and lower mortality; however, majority of studies are ecological. Two prospective studies were in specific subpopulations (elderly and stroke survivors). One prospective study could not account for individual-level smoking.	II

Strength of evidence definitions:

I = High: evidence is consistent, plausible, and precisely quantified and there is low probability of bias

II = Intermediate: evidence exists, but not entirely consistent, is not quantified precisely, or may be vulnerable to bias

III = Low: evidence is inconsistent, implausible, and/or may be vulnerable to bias severely limiting the value of the effect being described

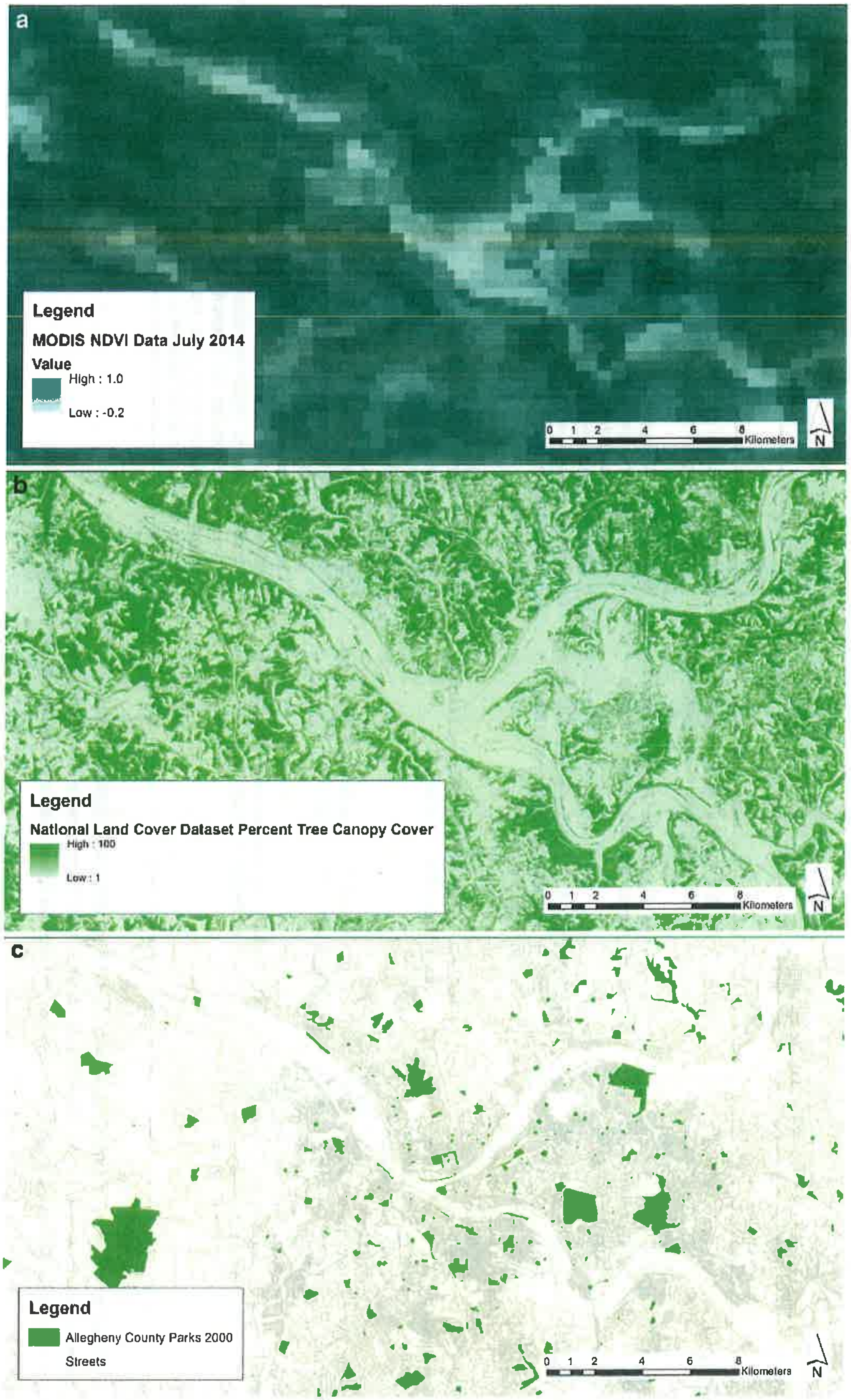

Fig. 2 Measures of exposure to greenness and different metrics of greenness. **a** NDVI. **b** Land cover datasets. **c** Park layers

Different exposure metrics present different advantages and drawbacks. Land-use datasets may provide more information about specific types of green spaces, potentially giving an indication of their quality or usability. However, specific designations may mischaracterize "green" land uses, for example parks that do not contain vegetation. Additionally, land-use files may be too coarse to capture small-scale vegetation, such as gardens and street trees. Conversely, vegetation indices do not provide qualitative information about the type of land use but may offer sufficient information if vegetative density itself is the instrumental exposure. Since land-use datasets are produced less frequently, analyses focused on these datasets may encounter problems with temporal mismatch of exposure and outcome data. This temporal mismatch is less common with vegetation indices because they are available at finer temporal intervals. Finally, land-use datasets may vary both between and within countries due to different underlying data availability and diverse land classification methodologies across different municipalities. Because vegetation indices cover the entire planet and are collected using uniform methodologies, they confer consistency and comparability across analyses.

While these are standard measures in the literature, there is some question as to the accuracy with which they characterize a person's greenness exposure. For example, residential greenness may not fully capture exposure among people who work or recreate away from home. Furthermore, very few studies address green space use, even in the physical activity literature, where the primary hypothesis is that higher surrounding greenness promotes physical activity through recreation in green spaces. Notable exceptions include studies in which participants wore global positioning systems (GPS) devices and accelerometers [26•, 27–29]. Though objective measures of greenness cannot account for the qualities that might make it usable or pleasant, NDVI has been found to be highly correlated with environmental psychologists' evaluations of green spaces [30].

Because greenness is correlated with other spatial and contextual factors, researchers have attempted to account for these associations in their studies to isolate the specific role that greenness might play in influencing health. For instance, Hystad et al. showed that in a birth cohort across Vancouver, the average NDVI levels within 100 m of each residence were correlated with predicted NO (−0.43), NO_2 (−0.42), $PM_{2.5}$ (−0.36), and black carbon (−0.31), as well as modeled traffic noise (−0.05), all noise (0.20), and neighborhood walkability (−0.58) [31•]. The investigators found that their associations were robust to adjustment for these moderately correlated factors. Other studies, such as Fuertes et al. [32], have stratified by population density and found similar effects of greenness among different strata of population density. Still, further attention is required to isolate the specific effects of greenness on health by accounting for these correlated factors.

Physical Activity

Greenness may encourage physical activity by providing both a walking or cycling destination and a venue for play and exercise [11]. A number of studies have assessed the association between green space and physical activity, typically in cross-sectional analyses where neighborhood greenness is derived from land-use files and physical activity is ascertained by survey. In general, this evidence supports a moderately positive association between green space and physical activity in adults (e.g., walking time, walking maintenance, meeting physical activity recommendations) [33–38]. Some analyses did not observe an association [39, 40], and Maas et al. found a negative association between green space and leisure-time physical activity [41]. In children, greenness has been associated with increased playtime outdoors [42], and in a study by Almanza et al. that used wearable GPS units and accelerometers, with higher odds of contemporaneous physical activity when in greener areas [26•]. Similar studies employing GPS units and accelerometers in children found that about half of weekend moderate–vigorous physical activity took place in green space [27], and that epochs of moderate–vigorous physical activity were significantly more likely to occur in green space (versus outdoors not in green space) for boys, but the relationship was not significant for girls [28]. Relatedly, greenness and forest proximity were associated with lower prevalence of excessive screen time (more so for children whose parents had more education) [43]. Of studies that included measures of perceived greenness, one found that both subjective and objective green space were associated with walking maintenance [44], while the other found that only perceived greenness was related to walking trips [45].

While individual cross-sectional analyses may limit causal inference, the strong consistency across studies after adjustment for a range of individual and area-level potential confounders (age, gender, individual socioeconomic status (SES), area-level SES, and population density) suggests that greenness may promote physical activity.

Overweight/Obesity

Greenness has been explored as an environmental determinant of obesity because of its potential association with physical activity. Primarily, studies of greenness and obesity were cross-sectional in design and measured BMI based on surveys, although some studies queried electronic medical records. In general, greater neighborhood greenness (and in one case, variation in greenness) was associated with lower likelihood of overweight or obesity. Mowafi et al. [46], however, found no association after adjustment for neighborhood SES, and Cummins and Fagg [47] found that green space was associated with increased odds of overweight and obesity.

Some effect modification by gender has been observed. In one study, green space was associated with a reduced likelihood of overweight and obesity among women but not men [48]; in another, it was associated with a reduced likelihood of physical activity and increased overweight/obesity in men but decreased overweight/obesity in women [49].

Findings among children have been mixed. The only prospective study found greenness to be associated with lower BMI *z* scores and lower odds of increasing BMI *z* scores between two follow-up times [50]. Another study found that greenness and forest proximity were associated with lower prevalence of overweight and obesity [43]. Liu et al. found that greenness was associated with decreased risk for overweight, but only among those in areas with greater population density [51]. One study found that street tree density but not park area was associated with lower obesity prevalence [52], and another study found that green space access was not associated with children's weight [53].

Despite the presumptive mechanism of physical activity, only a few studies analyzed it as a potential mediator. These results varied; in one, those further from green space were less likely to partake in physical activity and had higher odds of obesity than those living closer [54]. Another study found the opposite: higher levels of green space were associated with less physical activity (and increased overweight/obesity in men, but decreased overweight/obesity in women [49]). One study found that living close to a park was positively associated with physical activity, but not associated with overweight/obesity [19]. Finally, another study found that, even controlling for physical activity, the negative association between green space and weight (in women but not men) remained [48].

Several methodological shortcomings are common to these papers, which are almost all cross-sectional, and in which survey non-response could limit generalizability. Most analyses, however, controlled for a range of potential confounders (e.g., age sex, race, ethnicity, SES, and area-level SES and urbanicity). The general consistency of results suggests that there may be an inverse association between greenness and overweight/obesity; however, further study (and prospective analyses) is needed to establish temporality, explore mediation (e.g., by physical activity), and probe potential effect modification by gender.

Mental Health

Greenness may promote mental health by encouraging physical activity, fostering social cohesion, or providing a direct psychological benefit [7, 55]. Most studies of greenness and mental health were cross-sectional, survey-based, and used self-administered clinical scales to assess mental health status, though some extracted medical records [20, 56]. In general, greater neighborhood greenness or access to green space was associated with reduced risk of stress, propensity to psychiatric morbidity, psychological distress, depressive symptoms, clinical anxiety and depression prevalence, and mood disorder treatment in adults [18, 20, 22•, 56–62]. Though most studies considered objective greenness measures, Sugiyama et al. [23] found that those who perceived their neighborhood as highly green had higher odds of better mental health than those who perceived their neighborhood as least green. One study did not find any association between greenness and psychological distress [63], while an analysis of green space and emotional well-being in children found weak and inconsistent results, with modest protective effects in small cities [64].

A number of studies focused on mental health explored mediation. Three analyses found that the protective association between perceived or objective greenness and mental health remained even when controlling for physical activity and social cohesion [22•, 23, 58]. Among those who used woods or forest for physical activity, odds of poor mental health were reduced compared to non-users [65]. Fan et al. [60] explored mediation in different green space types, finding that parks mitigated stress through social support, while neighborhood vegetation mitigated stress directly but negatively affected social support. Finally, Maas et al. [56] found that loneliness partially mediated and perceived shortage of social support fully mediated the association between lower levels of green space and propensity to psychiatric morbidity.

The majority of studies of greenness and mental health are cross-sectional, though three studies with longer follow-up periods showed beneficial effects of green space on mental health. White et al. [57] used panel data from a longitudinal survey in the UK and found that greater urban green space was associated with lower risk of psychological distress. Annerstedt et al. [66] found a reduced risk of poor mental health among women who were physically active and had access to green space with specific qualities (serenity and space). Finally, without accounting for age, Astell-Burt et al. [67] found that green space was associated with better mental health among men, but not women. However, among men there was a stronger protective effect of green space on psychiatric morbidity in early to mid-adulthood. For older women, those with moderate green space had better mental health compared to those with low green space access.

Other limitations included possible selection bias due to survey non-response [23, 59, 60, 66], instances of temporal misalignment between greenness and health measures [61], and coarse green space measures that did not capture smaller elements like gardens and trees [56].

Despite these flaws, consistency among a large and diverse group of studies that employed sensitive psychological scales and adjusted for several individual- and area-level potential confounders suggests an association between green space and mental health. Further study, especially in prospective analyses, is warranted.

Birth and Developmental Outcomes

Greenness exposure may affect birth outcomes by altering maternal levels of physical activity, reducing maternal stress, enhancing social contacts among mothers, reducing maternal noise and air pollution exposure, and moderating ambient temperatures [68]. The effect of greenness on pregnancy and birth outcomes has been studied extensively in analyses across multiple countries. Studies generally involved birth registries where the mother's address at birth was linked to a measure of greenness, most commonly NDVI, and birth outcomes were assessed from medical records that presented few opportunities for systematic bias. Positive associations between greenness and birth weight were reported consistently across the majority of studies [31•, 69–72]. Other studies found that higher greenness exposure was linked to lower odds of a child being small for gestational age or preterm [31•], larger head circumferences [68], and lower infant mortality risk [73], although these findings were not replicated across studies.

The majority of analyses adjusted for race, maternal age, season of conception, area-level SES, and child's sex, minimizing concerns for confounding. While some birth registry studies were not able to account for alcohol or tobacco use [69] or maternal income or education [31•], most analyses were able to adjust for these factors. Some studies were able to additionally model complex exposures, including air pollution [31•, 68], neighborhood walkability, and noise [31•]. Associations between greenness and birth outcomes were robust to adjustment for these important covariates. Stronger associations between greenness and birth outcomes were observed among those whose parents had lower education and lower SES [68, 69, 71], as well as for mothers of white race as compared to immigrants [72].

A few studies considered greenness in relation to developmental outcomes and allergies in children, positing that beneficial effects may be mediated by physical activity; social engagement; reduced stress; and noise, heat, and air pollution reductions [74]. Distance to the nearest green space from a child's residence was positively associated with odds of hyperactivity and inattention [21]. Dadvand et al. [43] found that greenness and forest proximity was not associated with asthma or allergic rhinoconjunctivitis, but proximity to parks was associated with higher asthma prevalence. In another study, greenness was positively associated with allergic rhinitis and eye and nose symptoms in urban areas, but negatively associated with these symptoms in rural areas [32].

While some studies were limited by incomplete control for important potential confounders, the body of literature on greenness and birth outcomes indicates that there is strong evidence for an association between residential greenness exposure and birth weight. Findings for other birth and developmental outcomes are suggestive but require further evidence.

Cardiovascular Outcomes

Greenness exposure may affect levels of physical activity, stress, social engagement, noise, and air pollution exposure, which may drive cardiovascular disease risk [75–77]. Three ecological studies analyzed mortality records and found that areas with lower greenness had higher levels of stroke mortality [78] and cardiovascular disease mortality [16, 79]. Maas et al. [62] reviewed cross-sectional morbidity data from Dutch general practitioners and found that higher residential greenness was associated with lower odds of coronary heart disease. Markevych et al. [80] observed lower systolic and diastolic blood pressure among children from a German birth cohort who had higher residential greenness, after accounting for temperature, air pollution, noise, and urbanization. A cross-sectional survey in Australia demonstrated lower odds of hospitalization for heart disease or stroke for adults with higher variability in greenness around their homes, although no associations were seen for absolute greenness [81]. Finally, Villeneuve conducted a prospective survival analysis based in Ontario, Canada [82•]. After adjustment for air pollution exposure, higher levels of greenness were associated with lower risk of CVD, ischemic heart disease, and stroke mortality. While numerous covariates were included in analytical models, the authors did not have individual-level data on smoking.

A UK-wide analysis by Mitchell et al. found that higher levels of green space decreased inequities in circulatory mortality by area-level SES [16], while a Dutch study found that groups with lower levels of education had a greater health benefit from green space exposure compared to those with higher levels of education [62].

Two studies applied experimental approaches to examine the association between short-term exposure to simulated green spaces and blood pressure after short bouts of physical activity [83, 84] and found that subjects viewing videos of green, natural spaces had small reductions in blood pressure compared to those viewing urban scenes.

A small body of literature supports an association between greenness and a range of cardiovascular outcomes; however, the majority of these studies was cross-sectional and employed ecological study designs. One high-quality prospective analysis reinforced the links between greenness and cardiovascular mortality, but this analysis did not include individual-level information on important potential confounders. More prospective analyses with individual-level information on exposure and outcome are required to establish a causal relationship between greenness and cardiovascular outcomes.

Mortality

The mechanisms through which greenness affects health may ultimately affect mortality. The first mortality analysis took place in Japan, where researchers asked elderly participants about characteristics of their residential surroundings at baseline [85]. Five-year survival rates were highest among those reporting tree-lined streets near their residence. Since this initial study, several ecological analyses have examined larger-scale data, including a nationwide analysis using a land-use dataset from the UK [16]. The authors found a 6 % lower mortality rate comparing administrative areas in the highest quintile of greenness to the lowest. A similar study across the UK found that male cardiovascular and respiratory mortality rates decreased with increasing green space, but no associations were found for women [79]. An ecological analysis of census tracts in Florida found that areas with low greenness had the highest rates of stroke deaths [78], while a census-based analysis in New Zealand observed no associations between usable or total green space and mortality [86]. Villeneuve et al. [82•] examined mortality in Ontario, Canada and evaluated exposure to greenness based on the area around each participant's residence. They found that after adjustment for air pollution exposure, an increase in greenness was associated with reduced overall non-accidental mortality, driven by the cardiovascular outcomes described above. Using data on stroke survivors, Wilker et al. [87] found that higher greenness was associated with a lower mortality rate. Lachowycz and Jones tested whether self-reported walking would mediate the association between access to green space and mortality in an ecological study of residents of England [88]. While an association between greenness and walking was observed in all areas, the association between greenness and reduced mortality was only apparent in the most deprived areas. The authors also found no evidence that recreational walking explained the associations between greenness and mortality.

The small set of studies examining greenness and mortality is generally consistent and shows that increased greenness is associated with lower mortality. The majority of these studies, however, was based on ecological data that limit statements on causality. Three prospective cohort analyses have been conducted, although two studies have limited generalizability due to special populations (elderly and stroke survivors), while the third study was not able to completely account for smoking. More prospective cohort analyses are necessary to replicate these findings. In addition, while one study found that the association between greenness and mortality could not be explained by recreational physical activity, more research is required to explain the mechanism through which greenness affects mortality.

Inequalities

Greenness and access to green spaces is not equally distributed across space, and certain populations may have lower exposure and decreased access to these resources. Researchers have attempted to quantify inequalities in greenness exposure and green space access. Studies have demonstrated that neighborhoods with higher percentages of minorities in the USA [89] and lower SES in Australia [90] have lower levels of green space access, although one study in Melbourne, Australia found that there was no link between neighborhood SES and access to recreational open spaces [91]. An examination of nationwide US Census block group data showed that racial minorities were more likely to live in areas with lower tree canopy cover and higher impervious surfaces [17].

Researchers have also highlighted differential effects of greenness on health, with consistent evidence of stronger associations between greenness and health among low SES individuals. Multiple studies of greenness and birth outcomes found stronger associations among mothers who were of lower SES [68–70] and one study indicated differential effects by ethnicity [70]. Higher greenness appears to decrease the effect of income deprivation on all-cause and cardiovascular mortality [16], and participants with the lowest levels of education had the largest benefit from green space exposure in terms of chronic obstructive pulmonary disease [62]. In addition, the association between greenness and reduced mortality is strongest in the most deprived areas [88]. Greater green space has also been shown to be protective against psychological distress among more physically active subjects, but not among the least active [18]. Differential associations by sex are inconsistent. One study showed that women with higher levels of greenness in their census ward had lower levels of salivary cortisol, although similar results were not found in men [92]. In one study, green space was associated with a lower likelihood of overweight and obesity in women but not men [48]; in another, greenness was associated with a reduced likelihood of physical activity and increased overweight/obesity in men but decreased overweight/obesity in women [49]. Conversely, another study found that male cardiovascular disease and respiratory disease mortality rates decreased with increasing green space, but no associations were found for women [79]. In children, greenness was found to be positively associated with allergic rhinitis, and eye and nose symptoms in urban areas, but with reductions in risk in rural areas [32]. Additionally, proximity to a forest was associated with lower odds of excess screen time among children in Spain [43]. This association was strongest among children with parents of higher education compared to those with lower education.

Conclusions

Evidence linking greenness to various health behaviors and physical wellbeing continues to grow, and associations appear to be stronger for certain outcomes than others. Cross-sectional studies of physical activity have exhibited consistent results across a wide variety of study populations, suggesting a robust positive association with greenness. This connection is underscored by studies in which participants wore GPS devices and accelerometers, in which greenness was associated with greater odds of physical activity. Despite suggestions of a link between greenness and physical activity, the results of studies on greenness and weight status have been less conclusive, though some evidence points to an inverse association of greenness against overweight and obesity. Many processes—genetic, behavioral, and environmental—contribute to weight status, and further work is required to understand the relative contribution of greenness. A number of studies on mental health have found increased greenness to be associated with lower likelihood of psychological distress and other mental health outcomes and have begun identifying potential mediators such as physical activity, stress, and social cohesion, primarily in cross-sectional studies. Among children, there is consistent evidence from birth cohort studies that higher greenness during pregnancy is positively associated with birth weight, though studies of other birth outcomes are less conclusive. The mixed findings among the few studies on developmental health underscore the need for further work in this area. Studies examining the effects of greenness on cardiovascular disease and mortality rely mostly on ecological and cross-sectional analyses (excepting two high-quality prospective studies [82•, 87]) but suggest that greater greenness may be associated with lower cardiovascular disease prevalence and lower mortality.

In general, this relatively new line of inquiry has established interesting potential relationships between greenness exposure and health. The vast majority of studies, however, are cross-sectional, limiting the extent to which the often protective effect of greenness can be construed as causal. Studies will be subject to the possibility of self-selection (wherein healthier subjects or those with more health-promoting behaviors move to greener areas) until prospective analyses can be conducted.

Exposure characterization can be improved by emphasizing green space quality and subjects' use of green space in future studies, for example by gathering both objective and subjective measures and by replicating work done with wearable GPS devices and accelerometers. Outcome assessment can be improved through medical records extraction and other objective ascertainment.

Finally, the suggestion in some analyses that both green space access and its health benefits differ according to individual and neighborhood-level characteristics deserves further exploration. Age, gender, and especially SES may modify the association between greenness and health behaviors and outcomes. In particular, the finding that lower SES groups have less green space access but perhaps benefit more from greenness exposure deserves further study. If borne out, that dynamic may suggest one strategy to mitigate socioeconomic health disparities.

In summary, the body of literature assessing the effects of greenness on health provides some evidence that greenness may be beneficial for physical activity, obesity, mental health, birth outcomes, cardiovascular outcomes, and mortality. While further work is needed to firmly establish causal relationships, greenness shows promise as a modifiable and health-promoting exposure.

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Compliance with Ethics Guidelines

Conflict of Interest P. James, R.F. Banay, J.E. Hart, and F. Laden all declare no conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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