Review

Green Space Quality and Health: A Systematic Review

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Abstract: (1) Background: As cities densify, researcher and policy focus is intensifying on which green space types and qualities are important for health. We conducted a systematic review to examine whether particular green space types and qualities have been shown to provide health benefits and if so, which specific types and qualities, and which health outcomes. (2) Methods: We searched five databases from inception up to June 30, 2021. We included all studies examining a wide range of green space characteristics on various health outcomes. (3) Results: 68 articles from 59 studies were found, with a high degree of heterogeneity in study designs, definitions of quality and outcomes. Most studies were cross-sectional, ecological or cohort studies. Environment types, vegetation types, and the size and connectivity of green spaces were associated with improved health outcomes, though with contingencies by age and gender. Health benefits were more consistently observed in areas with greater tree canopy, but not grassland. The main outcomes with evidence of health benefits included allergic respiratory conditions, cardiovascular conditions and psychological wellbeing. Both objectively and subjectively measured qualities demonstrated associations with health outcomes. (4) Conclusion: Experimental studies and longitudinal cohort studies will strengthen current evidence. Evidence was lacking for needs-specific or culturally-appropriate amenities and soundscape characteristics. Qualities that need more in-depth investigation include indices that account for forms, patterns, and networks of objectively and subjectively measured green space qualities.

Keywords: green space qualities; parks; streetscape greeneries; environmental types; built environment; physical health; mental health; cardiovascular diseases; respiratory diseases; quality of life

1. Introduction

Green spaces are a crucial aspect of urban cities. They protect against many of the harmful impacts of rapid urbanisation on health. They also permit social and economic benefits by providing preferential settings for relaxation, building social connections, engaging in physical activity and feeling closer to nature, including resident wildlife [1]. Therefore, urban greening is an important strategy for addressing complex global issues such as climate change, sustainable urbanisation and health inequality. This is recognised via the United Nations Sustainable Development Goal (SDG) 11 target 7, which states “by 2030, providing universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities” [2].

Substantial research is dedicated to revealing the health benefits of green spaces [3]. While more green space tends to be good for health, such conclusions are not universally reported. Most research in this field tends to use measures of ‘greenness’ such as the normalised difference vegetation index (NDVI) to quantify green space exposure [4], ignoring substantial heterogeneity in the constituent qualities of green spaces that make...
them attractive for visiting and, in turn, support health and wellbeing. For example, green spaces may vary in terms of objectively measurable good qualities (e.g., presence of certain attractive elements, such as tree canopy, footpaths and seating) and others that are more subjective in nature (e.g., an emotional or spiritual connection to a particular green space). Bad qualities (e.g., proximity to a busy road and lack of accessibility) may discourage visitation and negate health benefits. Ignoring the constituent qualities that attract or discourage people to spend time in green spaces holds back the field from having more substantive impacts as a catalyst for improving community health and reducing inequities. Examining these qualities, both good and bad, may solve a missing link in our understanding of the relationship between green spaces and health [5].

Moreover, studying green space qualities has practical implications for urban planning. Driven by rapid densification, the compact, high-density city has become the dominant urban design worldwide. Not only does a compact city warrant multifunctional green spaces that can serve its diverse citizen population. It also presents a complex set of trade-offs between green space creation, regeneration and expansion on one hand, and the development of new, often competing land-use on the other (e.g., housing, infrastructure and commercial) [6]. Within space constrained contexts, modifying qualities of existing green spaces may offers an important way to maintain and improve quality of life in urban communities.

Research on the health benefits of green space qualities is still emerging and there are no consensus definition what green space quality is. We do not know which qualities can be modified, and which health benefits these modifications will bring (if any). To build capacities for research that attends to these issues, we conducted a systematic review to take stock of what research has been performed on green space qualities and health, with the broader aim of charting possible paths forward to strengthen the policy relevance of this research.

This systematic review aims to:
(a) Evaluate whether improving certain qualities of green space provides health benefits to the population;
(b) Identify and categorise all qualities of green space that have been investigated in previous primary studies; and
(c) Explore the extent of variations in design characteristics of these studies.

2. Materials and Methods

The reporting of this review was guided by the updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline [7]. This review was not registered a priori, nor was a protocol published separately.

2.1. Search Strategy

We searched the following databases for articles from inception up to 8 December 2020: MEDLINE via Ovid, Embase via Ovid, PsycINFO via Ovid, CINALH via EBSCO and Scopus. No language or publication date restriction was applied. An updated search was performed on 30 June 2021. The search was supplemented by a manual search of the reference lists from relevant systematic reviews.

The search strategy was a combination of three components: (health outcomes AND green space quality AND green space types). For health outcomes, we used both generic and specific search terms to capture all dimensions of physical and mental health, drawing from previous systematic literature reviews on green space and health [8-9], obesity and physical activity [10-11], birth outcomes [12], mental health [13-15], puberty timing [16] and menopause [17]. For green space quality, we combined the word “quality” and other determinant terms adapted from audit tools used for assessing the physical environment of parks [18]. For green space types, we used both generic and specific search terms to capture all types of green space in both urban and rural settings. The full search strategy is available in Supplementary File S1.
2.2. Study Selection

We included all human studies meeting the following criteria:

(a) Population: green space users of all ages and genders;
(b) Exposure: In the context of our review, green space quality refers to any attribute that can affect willingness to use and interaction of users with that space, including but not limited to intrinsic characteristics (size or patterns), features (vegetation, facilities or amenities), conditions (maintenance or safety) or user perception of its usefulness or quality. All types of natural and man-made green environments, including parks, streetscape greenery, urban open spaces, playgrounds, coastal parks with vegetation, etc., were included as long as they were defined by authors as green space. Studies where participants viewed digitalised renderings or photographs of green spaces without actual exposure were excluded. Studies that did not investigate any aspect of green space quality were excluded. The percentage of overall vegetation coverage and “greenness” (e.g., the normalised difference vegetation index) were not eligible as they are considered measures of green space quantity, unless specific vegetation types were analysed (e.g., tree canopy);
(c) Outcomes: Studies that investigated health outcomes, including but not limited to cardiometabolic, respiratory, reproductive, neurological and psychological health, and child development, were included. Studies that only measured behaviours (park usage, park-based activity, etc.) without assessing health outcomes were excluded;
(d) Study design: All observational and intervention studies, including randomised, quasi-randomised and non-randomised trials. We excluded non-English language studies, study protocols, conference abstracts, dissertations, reviews, qualitative studies, editorials, case studies and opinion pieces.

All retrieved data were imported into Covidence (Veritas Health Innovation, Australia) to remove duplicates. Two reviewers (PYN and HR-A) independently screened all titles and abstracts in duplicate and excluded studies that did not meet the inclusion criteria. Studies that were included from title/abstract screening had their full text reviewed in duplicate by the same two reviewers and reasons for exclusion were noted. Disagreement was resolved by discussion with senior reviewers (XF and TA-B). All stages of study screening were conducted in Covidence.

2.3. Data Extraction and Quality Appraisal

One reviewer (P-YN) extracted the data using a standard data extraction form and a second reviewer (HR-A) validated 10% of the studies for accuracy. The data extracted included: study characteristics (location, time, settings), population’s demographic and clinical characteristics, green space types, green space quality domains, health outcomes and corresponding measures of association. We also recorded the tools used to assess green space quality and health outcomes, effect measures reported, types of statistical analyses conducted and any adjustment for confounding factors. Based on the effect measures and 95% confidence intervals, we recorded the direction of effect for each study, i.e., whether the study presented some evidence of protective associations, some evidence of risk associations, or no significant associations at all.

One reviewer (P-YN) appraised the methodological quality of all included studies using the quality assessment tools for the appropriate study types [19] and the second reviewer (HR-A) validated 10% for accuracy. Because these tools do not provide for ecological studies, the existing tool for observational cohort and cross-sectional studies were adapted by adding 3 criteria addressing ecological fallacy, spatial autocorrelation and uncertainty in fitting spatial data [20,21]. Based on the list of applicable criteria, each study was given an adjusted quality score of 0–10 (Supplementary File S2). Disagreement was resolved with consensus via discussion with senior reviewers (XF and TA-B), if required.
2.4. Data Analysis

We used inductive categorisation to develop a set of domains of green space quality based on definitions reported in the included studies and stratified the findings of the studies based on these quality domains. Due to the heterogeneity of exposure, intervention and outcomes, meta-analysis was not conducted.

3. Results

In the initial search, we identified 30,220 records, and 7 additional records were added through manual searching. After removing duplicates, 23,745 studies were included for title/abstract reviews, from which 118 full texts were selected for further screening. Fifty full texts were excluded (Supplementary File S3). The final sample comprised 68 articles from 59 studies (Figure 1).
3.1. Setting and Participant Characteristics

The 59 studies (68 articles) were conducted in 19 countries/territories and were published from January 2009 to April 2021. Most articles were based on studies conducted in the United States (US) \(n = 17\), Australia \(n = 12\) and United Kingdom (UK) \(n = 10\). The mean age of the participants ranged from 4.5 to 76.5 years. A total of 5 studies included only people aged 55 years or older \[22–26\]; 11 studies included only people under 16 years old \[27–37\]. Most studies were balanced in gender distribution, with proportions of female participants ranging from 32 to 67%. Four studies exclusively examined female participants \[38–41\].

Cities and inner-city neighbourhoods were the predominant settings. Seven studies took place in multi-ethnic and/or socioeconomically deprived areas \[29–31,37,42–44\]. One study specifically examined the differential impact of green space on children of South Asian descent versus Caucasian children \[37\]. The characteristics of included studies are summarised in Table 1.
| Study          | Location * | Study Design | Sample Size ** | Population | % Female | Age | Description of Green Space Types                                                                 | Mediating Factors | Factors Adjusted in Analysis                                                                 |
|---------------|------------|--------------|----------------|------------|----------|-----|-------------------------------------------------------------------------------------------------|------------------|---------------------------------------------------------------------------------------------|
| Aerts, 2020   | Belgium    | Eco          | 1872 census tracts | Children aged 6–12 and 13–18 years | N/A ̸= Range: 6–18 | Grassland (permanent grassland, hay meadows and lawns); gardens (ornamental gardens and vegetable gardens); forest (coniferous, mixed and broadleaved woodlands) | -                | Time, green space coverage, mean annual PM10 concentration, % houses with basic or insufficient, administrative region |
| Astell-Burt, 2019 | New South Wales, Australia | CS-Pros | 46,786 | Adults ≥ 45 years old | 53.8 | Mean: 61.0 ± 10.2 | Tree canopy, grass and other low-lying vegetation | -                | Age, sex, household income, employment status, education, couple status                      |
| Astell-Burt, 2020 | New South Wales, Australia | CS-Pros | 109,688 | Adults ≥ 45 years old | 52.3 | Median range: 55–64 | Trees and grass | -                | Age, gender, economic status, education, household income, couple status, area-level disadvantage, total green space |
| Astell-Burt, 2020 | New South Wales, Australia | CS-Pros | 46,786 | Adults ≥ 45 years old | 53.8 | Median range: 55–64 | Street trees and trees in parks | -                | Age, gender, couple status, education, household income, employment                          |
| Astell-Burt, 2020 | New South Wales, Australia | CS-Pros | 45,644 | Adults ≥ 45 years old | N/R | N/R | Tree canopy, open grass and shrubs | -                | Age, sex, living arrangement, education, household income, economic status                    |
| Astell-Burt, 2021 | New South Wales, Australia | CS-Pros | 45,644 | Adults ≥ 45 years old with type 2 diabetes mellitus | N/R | N/R | Tree canopy, open grass | -                | Age, sex, living arrangement, education, household income, economic status                    |
| Bai, 2013     | Kansas, USA | CSS          | 893            | Urban residents living within 0.5 miles from parks | 60.7 | Mean: 50.9 ± 16.5 | Parks | -                | Age, sex, race/ethnicity, income, past park use                                               |
| Bird, 2016    | Canada      | CS-Retro     | 380            | Caucasian children 8–10 yo with at least one obese parent | 52.4 | Mean: 9.7 ± 0.89 | Parks and open spaces | -                | Age, sex, puberty, household income                                                          |
| Bojorquez, 2018 | Tijuana, Mexico | CSS      | 2345           | Urban female residents | 100.0 | Mean: 37.0 | Parks | Being active in a public space | Age, marital status, children, SES (employment, education), park coverage                    |
| Camargo, 2017 | Bucaramanga, Colombia | CSS | 1392 | Urban park visitors | 58.4 | Median: 42 (28–55) | Zonal and local urban parks | -                | Education, health status, walking difficulty, anxiety/depression, visiting with a companion, active park use |
Table 1. Cont.

| Study          | Location * | Study Design | Sample Size ** | Population Description | % Female | Age | Description of Green Space Types | Mediating Factors | Factors Adjusted in Analysis |
|----------------|------------|--------------|----------------|------------------------|----------|-----|----------------------------------|-------------------|-------------------------------|
| Carter, 2014 [52]              | Perth, Australia | CSS          | 440             | Residents in inner-city and suburban neighbourhoods | 64.0     | Range: 45–54 | Parks, gardens, play and social green spaces, bushland, sports fields, streetscapes, private yards | Age, SES (income, education), family structure, living arrangement, neighbourhood |
| Dennis, 2020 [53]               | Manchester, UK | Eco          | 1673 LSOAs     | Urban residents in young vs. old neighbourhoods of various income levels | N/R      | Old areas: >23.6% population are ≥60 yo Young areas: ≤23.6% | Public parks, recreational spaces (playing fields, allotments and sports facilities), landscaped open spaces, private gardens, institutional land, previously-developed land, peri-urban and informal urban greenery (street trees, road verges) | Age, sex, income, employment, barriers to housing and services, educations/skills/training, crime levels |
| Dillen, 2012 [54]              | Netherlands | CSS          | 1553           | General population | 52.0     | Median range: 45–65 | Streetscape greenery Green areas: parks, forests, nature and recreation areas | - | Age, sex, SES (education, income) |
| Dobbinson, 2020 [55]            | Melbourne, Australia | QES         | 1670           | Park visitors in a deprived neighbourhood | 44.7     | Median range: 34–37 | Parks | - |
| Donovan, 2018 [56]              | New Zealand | CS-Retro     | 39,108         | Adults aged 18 | 48.7     | Mean: 18.0 ± 0 | Urban parkland/open space, grassland, herbfield, orchards, vineyards, crops, grassland, freshwater and saline vegetation, flaxland, gorse, shrublands, mangroves, forests and hardwoods | - | Premature birth, low birth weight, antibiotic use, parental smoking, ethnicity, birth order and number of siblings, and parental occupation |
| Droomers, 2015 [57]             | Netherlands | QES          | 48,132         | Residents living in neighbourhoods with history of green intervention projects | N/R      | N/R | Parks, natural playgrounds, community gardens or fruit orchards, children’s farms, fishponds, public allotment gardens, etc. | - | Living circumstances, neighbourhood, characteristics, safety |
| Dzhambov, 2018 [58]             | Plovdiv, Bulgaria | CSS         | 399            | High school and university students 15–25 yo | 32.0     | Mean: 17.89 ± 2.27 | Any green space | Restorative quality, social cohesion, physical activity, noise annoyance, perceived air pollution | Age, sex, ethnicity individual-level SES, time spent at home/day, duration of residence, population density, month |
| Egorov, 2020 [59]               | North Carolina, USA | CSS       | 186            | Urban residents | 67.2     | Mean: 37.1 | Trees and forest, grass and other herbaceous | - | Age, smoking status, education, BMI, density of residential units, concentration of NOx from local traffic, geographic coordinates |
| Study | Location * | Study Design | Sample Size ** | Population | % Female | Age | Description of Green Space Types | Mediating Factors | Factors Adjusted in Analysis |
|-------|-------------|--------------|----------------|------------|----------|-----|-----------------------------------|-----------------|-------------------------------|
| Feng, 2018 [39] | Australia | CS-Pros | 3897 | Mothers in postpartum period | 100.0 | Median range: 35–39 | Parkland | - | ARIA score, SEIFA score |
| Feng, 2019 [38] | Australia | CS-Pros | 3843 | Mothers in postpartum period | 100.0 | Median range: 40–44 | Parkland | - | Maternal age, SES (education, employment), years since childbirth, indigenous status, area disadvantage, remoteness (sea & aria), family structure |
| Francis, 2012 [60] | Perth, Australia | CS-Pros | 911 | Residents moving to newly-built homes | 62.0 | Median range: 40–59 | Public open spaces: parks, recreational grounds, sports fields, commons, esplanades and bushland/wilderness | - | Age, sex, SES (income, employment, education), marital status, children living at home, neighbourhood SES |
| Gernes, 2019 [28] | Ohio & Kentucky, USA | CS-Pros | 478 | Children aged 7 years | Cases: 42.4 | Control: 49.0 | Mean: 7.0 ± 0 | Trees and grass | - |
| Herranz-Pascual, 2019 [61] | Vitoria-Gasteiz, Spain | CSS | 137 | Urban park visitors | | | Mean: 42.3 ± 14.2 | Urban parks | - |
| Honold, 2016 [62] | Berlin, Germany | CSS | 32 | Residents living in inner-city neighbourhoods | 59.4 | Mean: 36.0 ± 10.2 | View of vegetation from windows | - | Age, exercise, range of view, perceived chronic stress |
| Jafafari, 2020 [63] | Tehran, Iran | Eco | 87 hexagons | General population | N/R | N/R | Green space | Air pollution | - |
| Jarvis, 2020 [64] | Vancouver, Canada | CSS | 1,960,575 | General population | 51.7 | Median range: 25–44 | Coniferous trees, deciduous trees, shrubs and grass-herbs | - | Age, sex, racial/cultural background, education level, household income, persons < 18 years old in household, urbanicity |
| Jiang, 2020 [65] | USA | Cross-sectional study | 212 | General population | 57.1 | Median range: 30–45 | Tree canopy, low-level vegetation | - | Age, income |
| Jonker, 2014 [66] | Netherlands | Eco | 1190 neighbourhoods | General population | N/R | N/R | Any green space except horticulture and streetscape vegetation | - | Sex, neighbourhood income, household disposable income, nursing home migration of frail elderly |
| Study         | Location     | Design | Sample Size | Population                                                                                   | % Female | Age                | Description of Green Space Types                                         | Mediating Factors                                                                 | Factors Adjusted in Analysis                                                                 |
|--------------|--------------|--------|-------------|--------------------------------------------------------------------------------------------|----------|--------------------|--------------------------------------------------------------------------|---------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Kim, 2014    | Texas, USA   | CSS    | 61          | Primary school students 9–11 yo from a deprived area with large Hispanic population            | 60.7     | Mean: 10.1 ± 0.67  | Tree canopy                                                             | -                                                                                     | Sex, maternal marital status and education, number of cars, neighbourhood satisfaction, accessibility to play areas |
| Kim, 2016    | Texas, USA   | CSS    | 92          | Primary school students 9–11 yo from a deprived area with large Hispanic population            | 62.0     | Mean: 10.0 ± 0.68  | Tree canopy                                                             | -                                                                                     | Age, sex, maternal employment status, physical activity time, TV watching hours, neighbourhood environmental perceptions |
| Kim, 2021    | Los Angeles, USA | Eco  | 2301 census tracts | General population                                                                                 | N/R      | N/R                | Private green spaces (yards, gardens, landscaped areas), semi-public green spaces (golf courses, schools, cemeteries, agricultural lands), public green spaces (parks and recreational areas) | -                                                                                     | Poverty rate, education, ethnic group, children population, senior population          |
| Kruize, 2020 | Europe       | CSS    | 3947        | Urban residents                                                                                | 55.4     | Mean: 51.4 ± 16.0  | Natural outdoor environment: any outdoor spaces that contain green or blue natural elements (street trees, forests, city parks, water bodies) | -                                                                                     | Age, sex, education, ndvi within 300 m, city                                          |
| Lai, 2019    | New York City, USA | Eco | 174 zip codes | General population                                                                                 | N/R      | N/R                | Street trees                                                             | -                                                                                     | Buffering traffic noise and air pollution                                               |
| Leng, 2020   | Harbin, China | CSS   | 4155        | Urban residents of a winter city                                                                  | 47.7     | Mean: 54.6 ± 10.3  | Any green space                                                          | -                                                                                     | Age, sex, SES (education), smoking, cardiovascular family history                      |
| Marseille, 2015 | UK           | BAS   | 127         | Elderly ≥ 55 years who participated in outdoor walks                                             | 55.5     | Range: 55-74       | Natural and semi-natural places, green corridors, urban green spaces, farmland, urban public spaces, coastal spaces | Perceived restorativeness                                                        | Type of environments, walk characteristics (duration, intensity)                       |
| McCarthy, 2017 | USA          | CSS   | 13,469      | Children in elementary schools in a multi-ethnic, deprived region                                | 49.2     | Mean: 9.7 ± 0.99   | Parks                                                                    | -                                                                                     | Age, sex, race/ethnicity, SES (education, income), nativity, marital status, children in household, self-reported health |
| McEachan, 2018 | UK           | CS-Pros| 805         | Children of age 4 of South Asian parents in a multi-ethnic, deprived city                       | 50.0     | Mean: 4.5 ± 0.4    | Public parks, play areas for children, sports fields, any natural habitats with plants and vegetation | -                                                                                     | Demographics, SES, maternal health behaviours, maternal mental wellbeing                |

**Table 1. Cont.**
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| Study                | Location * | Study Design | Sample Size ** | Population Description | % Female | Age | Description of Green Space Types | Mediating Factors | Factors Adjusted in Analysis |
|----------------------|------------|--------------|----------------|------------------------|----------|-----|--------------------------------|-------------------|------------------------------|
| Mears, 2020 [32]     | Sheffield, UK | Eco | 345 LSOAs      | Children in first and final years of primary school | N/R      | Range: 4–5 and 10–11      | Any natural land covers, including water | -                | Age, sex, income deprivation, air pollution, address density |
| Mears, 2020 [42]     | Sheffield, UK | Eco | 345 LSOAs      | General population in a highly-deprived region | N/R      | N/R            | Any natural land covers, including water | -                | Age, sex, income deprivation, air pollution, smoking rates, address density |
| Ngom, 2016 [71]      | Montreal and Quebec, Canada | Eco | N/A            | General population | N/R      | N/R            | Parks and woodlands, golf courses or any sport facilities | -                | Age, ambient air pollution, immigrant population, total population, social and material deprivation scores |
| Nishigaki, 2020 [26] | Japan      | CSS | 126,878        | Elderly ≥ 60 years with pollen allergy | 51.5     | Median range: 70–74      | Fields (rice paddy, crops), grassland, trees (deciduous, evergreen) | -                | Age, sex, education, household income, living with others, employment, frequency of going outside, driving a car, residence duration, total daylight, annual snowfall amount, annual rainfall, residential population density |
| Orstad, 2020 [72]    | New York City, USA | CSS | 3652           | Urban residents in areas with high prevalence of obesity | 58.9     | Median range: 45–64      | Parks   | Park use for physical activity, park crime | Age, sex, race/ethnicity, language of interview, SES (education, income, employment, car ownership), marital status, BMI, perceived traffic volume, perceived retail access, survey wave and strata |
| Parmes, 2020 [35]    | Europe     | CSS | 8063           | Children aged 3–14 years | 47.7     | Range: 3–14       | Green urban areas, sport and leisure facilities, broad-leaved forest, coniferous forest, mixed forest, natural grassland, moors and heathland, sclerophyllous vegetation, transitional woodland/shrub | -                | Age, sex, BMI, parental history of allergy, maternal education, parental smoking |
| Pazhouhanfar, 2018 [73] | Gorgan, Iran | CSS | 250            | Urban park visitors | 57.3     | N/R            | Parks   | -                | Age, sex, index of multiple deprivation |
| Pope, 2018 [43]      | Sandwell, UK | CSS | 578            | Urban residents in a deprived area | 51.1     | Median range: 40–59      | Any green space | -                | Age, sex, ethnicity (indigenous), non-English speaking, family SES, family structure, SEIFA score, ARIA score, neighbourhood safety |
| Putra, 2020 [36]     | Australia  | CS-Pros | 4969          | Children 4–15 yo | 48.7     | Range: 4–15       | Parks, playground and place space | -                | Age, sex, ethnicity (indigenous), non-English speaking, family SES, family structure, SEIFA score, ARIA score, neighbourhood safety |
| Study                  | Location *     | Study Design | Sample Size ** | Population         | % Female | Age                  | Description of Green Space Types                             | Mediating Factors                                                                 | Factors Adjusted in Analysis                                                                 |
|------------------------|----------------|--------------|----------------|---------------------|----------|----------------------|-----------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Reid, 2017 [74]        | New York City, USA | CSS         | 1387           | Urban residents     | 63.6     | Mean: 44.7 (Range 18–90) | Streetscape greenery                                            | Age, sex, race/ethnicity, season, neighbourhood tenure, individual SES (income, education), area-level SES (% living below poverty, % unemployed), \no2, % park and non-park open space |
| Richardson, 2018 [41]  | Scotland       | CS-Pro       | 46,093         | Mothers             | 100.0    | Median range: 25–29   | Natural space: all public and private natural surfaces (vegetation, water, sand, mud and rock) | Infant’s sex, parity, gestational age, year of birth, season of conception, maternal age, height, education, ethnicity, tenure, smoking during pregnancy |
| Rundle, 2013 [75]      | New York City, USA | CSS         | 13,102         | Urban residents     | 64.0     | Median: 45            | Parks                                                           | Age, sex, race/ethnicity, individual SES: education, neighbourhood SES: % residents in poverty, %black/African American, %Latino/Hispanic, % park land by park size |
| Sander, 2017 [76]      | Ohio, USA      | Eco          | 546 census blocks | General population | N/R      | Mean: 43.02 ± 4.37    | Publicly accessible conservation lands, recreational parks and cemeteries | -                                                                                   | Age, ethnicity, education, urban development intensity, population density, household income |
| Shen, 2017 [77]        | Taipei, Taiwan | Eco          | 48 districts    | Urban residents     | N/R      | N/R                  | Green structure                                                 | Temperature, primary and secondary air pollutants                                        | -                                                                                           |
| Stark, 2014 [78]       | New York City, USA | CSS         | 44,282         | Urban residents     | 58.5     | Mean: 26.6 ± 5.5      | Parks                                                           | Age, sex, race/ethnicity, SES (education, income), nativity, marital status, children in household, self-reported health |
| Stas, 2021 [79]        | Belgium        | CCS          | 189            | Adults ≥ 20 years old with pollen allergy | 59.3     | Mean: 40.4 ± 9.9      | Gardens, grassland and forests                                 | -                                                                                   | Age, sex, exposure to birch pollen and air pollutants, geographic regions               |
| Sugiyama, 2009 [25]    | UK             | CSS          | 271            | Elderly ≥ 65 yo     | 60.0     | Mean: 75 ± 7.2        | Neighbourhood open spaces: parks, community gardens, play and sports areas, village greens, river or canal banks, beaches | -                                                                                   | Age, functional capability, education                                                       |
| Tan, 2019 [23]         | Tainan, Taiwan; Hong Kong | CSS   | 326            | Elderly ≥ 55 yo     | 56.0     | Median range: 70-79   | Urban green space                                               | -                                                                                   | Age, park usage                                                                           |
| Study       | Location * | Study Design | Sample Size ** | Population               | % Female | Age               | Description of Green Space Types                                                                 | Mediating Factors                                                                 | Factors Adjusted in Analysis                                                                 |
|-------------|------------|--------------|----------------|--------------------------|----------|-------------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Tsai, 2016  | USA        | Eco          | 52 MSAs        | General population       | N/R      | N/R               | Forests (woody vegetation > 6 m in heights, including deciduous, evergreen and mixed); shrubland (woody vegetation and young trees < 6 m in heights); herbaceous (grassland, wildflowers) | -                                                                                       | Total population, total housing units, household income, % African American population |
| Vries, 2013 | Netherlands| CSS          | 1641           | General population       | 51.0     | Mean: 51.0 ± 16.0 | Any visible streetscape vegetation: flower boxes, green facades, view of woodlands, etc.        | Stress, social cohesion, green activity                                                | Age, sex, SES (education, income), life events, children, smokers, excessive drinkers       |
| Wang, 2019  | Philadelphia, USA | Eco | 369 census tracts | General population | 53.4     | N/R               | Tree canopy, grass cover and shrub cover with area ≥ 83.6 m²                                   | -                                                                                       | Age, sex, ethnicity, education, population density, land area                             |
| Wheeler, 2015 | UK       | Eco          | 31,672 LSOAs   | General population       | N/R      | N/R               | Any natural landscape                                                                         | -                                                                                       | Age, sex, SES (income, education and employment), urban/rural status, indices of deprivation |
| Wood, 2017  | Perth, Australia | CS-Pros | 492            | Residents moving to newly-built homes | 61.6     | Mean: 47.8 ± 12.1 | Parks, gardens, reserves, grassed open spaces and any freely-accessible sports fields         | -                                                                                       | Age, sex, SES (income, education, employment), marital status, children living at home     |
| Wood, 2018  | Bradford, UK | CSS          | 128            | Urban park visitors in a multicultural, deprived area | 46.0     | Median range: 36–45 | Formal parks and recreation grounds                                                              | -                                                                                       | Age, sex, ethnicity, connected to nature                                                |
| Wu, 2017    | California, USA | Eco | 543 districts  | Children in public elementary schools | 49.1     | Range: 5–12       | Forest, grassland, tree canopy                                                                  | -                                                                                       | Sex, household income, race                                                               |
| Wu, 2018    | North Carolina, USA | Eco | 187 census tracts | General population | N/R      | N/R               | Forest, grassland, tree canopy, and greenway                                                   | -                                                                                       | Age group, population density, household income, %Asian population                      |
| Wyles, 2019 | UK         | CSS          | 4515           | General population       | 52.2     | Median range: 35–44 | Any open space: parks and canals in cities and towns; coast and beaches; farmland, woodland, hills and rivers in the countryside | Connectedness to nature                                                                | Age, sex, SES, activities taken during visit, average time spent, distance to site, mode of transport, presence of companions |
| Zhang, 2017 | Netherlands| QES          | 223            | Residents from two neighbourhoods with contrasting green space qualities | 55–61    | Mean: 49.6 years (exposure) 39 years (comparison) | Any green space                                                                                   | Neighbourhood satisfaction                                                              | Quantity of green space, age, length of residence, income                               |
| Study          | Location     | Study Design | Sample Size ** | Population | % Female | Age | Description of Green Space Types                                                                 | Mediating Factors                                                                 | Factors Adjusted in Analysis                      |
|---------------|--------------|--------------|----------------|------------|----------|-----|------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------|
| Zhang, 2019   | Guangzhou,  China | CSS         | 250            | Urban park visitors | 58.0     | Median range: 31–45 | Park with a flowers garden, an entertainment and leisure zone, an elderly activity area, a forest rest zone, and a logistics management zone | Emotional responses, behavioural activities in parks                               | -                                                 |
| [88]          |              |              |                |            |          |     |                                                                                                 |                                                                                   |                                                   |
| Zhang, 2019   | Hong Kong    | CSS         | 909            | Residents ≥ 65 years from elderly health centres and community centres | 66.3     | Mean: 76.5 ± 6.0 | Parks | Age, sex, education, area-level SES, marital status, living arrangement, housing type, household with car, type of recruitment centre, number of current health problems | -                                                 |                                                   |
| [24]          |              |              |                |            |          |     |                                                                                                 |                                                                                   |                                                   |
| Zhu, 2020     | Harbin, China | CSS         | 240            | Urban park visitors | 43.0     | Median range: 20–29 | Island/archipelago within a city | -                                                                         | -                                                 |
| [89]          |              |              |                |            |          |     |                                                                                                 |                                                                                   |                                                   |

* Abbreviations: CCS: case-crossover study; CSS: cross-sectional study; CS-Retro: retrospective cohort study; CS-Pros: prospective cohort study; QES: quasi-experimental study; BAS: before-after study; Eco: ecological study; ** Default unit is person unless specified otherwise. Abbreviations: DA: dissemination area; LSOA: lower layer super output area; MSA: metropolitan statistical area. * analysis was stratified by sex.
3.2. Study Designs

Most included studies were cross-sectional \((n=32)\), followed by ecological studies \((n=16)\) and cohort studies \((n=15)\). Before-after \((n=1)\), quasi-experimental \((n=3)\) and case-crossover designs \((n=1)\) were rare (Table 1). The latter were relatively newer approaches published from 2015 onwards (Figure 2). All cohort studies were nested in existing longitudinal studies, usually with an additional cross-sectional survey for green space use and perceptions conducted after the initial survey waves. The follow-up time for longitudinal studies ranges from 2 to 18 years [56]. The quasi-experimental studies [55,57,87] had intervention and control groups selected in a non-random manner from two neighbourhoods with pre-determined green space qualities. The before-after study [22] was conducted among participants who participated in outdoor nature walks. The cross-over study [79] bi-directionally matched case days with the highest symptom severity scores to control days with the lowest scores, hence participants served as their own control. Among cross-sectional surveys, eight studies used convenience sampling by recruiting from park visitors [23,44,51,59,61,73,89,90]. The mean adjusted quality score among 68 articles was 0.49 ± 0.12 (scale 0–1).

![Figure 2. Published studies over the years, by study design.](image)

3.3. Definition of Green Space

Most studies \((n=42)\) used a loose definition of green space to include any natural or open space, encompassing urban green space, private and community gardens, public open spaces, bushland and forest reserves, etc. Eleven studies included playgrounds and sports fields [25,35–37,52,53,57,60,67,71,84]. Seven studies included streetscape greenery, which referred to any vegetation cover that gave the street a green appearance [52–54,68,69,74,81]. Forty-seven studies used data from a geographic information system (GIS) to identify green spaces or evaluate green space characteristics. One study examined neighbourhood vegetation as viewed from within the house [22]. The most common buffer size for GIS analysis was 0.5 mile (approximately 800 m), generally aligning with a 10-min walk [82]. Detailed definition of green space in each study is outlined in Table 1.

3.4. Outcomes

A range of health outcomes were reported, which were classified into physical (reported by 34 studies), psychological \((n=25)\), combined physical/psychological \((n=10)\), quality of life \((n=5)\), or developmental outcomes \((n=3)\). Twenty-seven studies used objective measures of outcomes, mainly assessing physical outcomes (Table 2).
Table 2. Mapping of measures used for assessment of green space qualities and outcomes.

| Green Space Quality Domain | All Studies | Studies Using Objective Measures to Assess Green Space Quality | Psychological Outcomes | Physical Outcomes | Combined Physical-Psychological Outcomes | Developmental Outcomes | Quality of Life Outcomes |
|----------------------------|-------------|-------------------------------------------------------------|------------------------|-------------------|----------------------------------------|------------------------|--------------------------|
|                            |             |                                                             | Both Subjective and Objective Measure * | Objective Measure Only | Both Subjective and Objective Measure * | Objective Measure Only | Both Subjective and Objective Measure * | Objective Measure Only | Both Subjective and Objective Measure * | Objective Measure Only |
| Environment/land cover type | 22          | 20                                                          | 8 (36.4%)              | 1                 | 12 (54.5%)                              | 8 (18.2%)              | 1 (4.5%)                              | 0 (0.0%)                  | -                                           |
| Natural features           | 15          | 11                                                          | 5 (33.3%)              | 0                 | 5 (33.3%)                              | 4 (20.0%)              | 0 (0.0%)                              | - (13.3%)                 | 2 (13.3%)                                   |
| Infrastructure and amenities | 14         | 10                                                          | 4 (28.6%)              | 0                 | 6 (42.9%)                              | 2 (14.3%)              | 0 (0.0%)                              | - (21.4%)                 | 0                                           |
| Size                       | 11          | 11                                                          | 2 (18.2%)              | 1                 | 6 (54.5%)                              | 2 (18.2%)              | 0 (0.0%)                              | - (18.2%)                 | 2 (18.2%)                                   |
| Shape, pattern and connectivity | 8    | 8                                                           | 0 (0.0%)               | -                 | 7 (87.5%)                              | 0 (0.0%)               | - (0.0%)                              | - (12.5%)                 | 1 (12.5%)                                   |
| Safety                     | 6           | 0                                                           | 2 (33.3%)              | 0                 | 1 (16.7%)                              | 2 (33.3%)              | 0 (0.0%)                              | - (33.3%)                 | 0                                           |
| Cleanliness and absence of incivilities | 5  | 4                                                           | 1 (20.0%)              | 1                 | 3 (60.0%)                              | 0 (0.0%)               | - (0.0%)                              | - (20.0%)                 | 1 (20.0%)                                   |
| Peacefulness               | 3           | 0                                                           | 2 (66.7%)              | 0                 | 0 (0.0%)                              | 1 (33.3%)              | 0 (0.0%)                              | - (33.3%)                 | 1 (33.3%)                                   |
| Perceived quality/Satisfaction with quality | 7  | 0                                                           | 2 (28.6%)              | 0                 | 3 (42.9%)                              | 1 (0.0%)               | - (28.6%)                             | 0 (0.0%)                  | -                                           |
| Combination of features    | 13          | 6                                                           | 6 (46.2%)              | 0                 | 5 (38.5%)                              | 5 (38.5%)              | 0 (0.0%)                              | - (15.4%)                 | 0                                           |

* Expressed as a percentage of all studies under respective green space quality domain.
The most common tools used for physical outcomes were body mass index (BMI) \((n = 9)\) [29,31,32,38,50,75,76,78,80], together with its associated anthropometric measures such as the percentage of truncal fat [27] and obesity/overweight [32,70]. Six studies investigated cardiovascular conditions such as hypertension, diabetes and coronary heart diseases [47,49,59,70,71,82]. Ten studies investigated respiratory outcomes, such as asthma and other allergic respiratory diseases [28,34,35,63,67,69,77,79,82]. The most common tools used for psychological outcomes were the Kessler psychological distress scale (K6-PD or K10-PD) [39,45,60] and the mental health inventory scale (MHI-5) [54,68,81]. All questionnaires used to measure psychological outcomes were self-reported by participants, indicative of the inherent subjectivity of this outcome domain. The strengths and difficulties questionnaire (SDQ) was used in studies assessing developmental outcomes. Lastly, five studies used various versions of the short form survey (SF-8, SF-12, SF-36) [23,52,54,65,81], which assess up to eight domains of health status, including physical functioning, physical role, bodily pain, general health, vitality, social functioning, emotional role, and mental health [91]. Detailed definitions of health outcomes and assessment tools are outlined in Table 3 and Supplementary File S4.

### 3.5. Green Space Qualities

Green space qualities were classified into 10 domains. Detailed definitions of green space qualities in each study is outlined in Table 3.

#### 3.5.1. Environment/Land Cover Types

There was one before-after study, seven cohort studies, one case-cross over study, seven cross-sectional studies and six ecological studies under this domain. All studies used different land cover or environment classification, commonly via adopting definitions of the data sources, some adapting [39,53,83,85] or developing their own typologies [22,86]. Detailed definitions of environment types were outlined in Table 3.

Overall, a higher land-cover diversity in the neighbourhood was protective for chronic morbidities [53] and childhood asthma [56]. Some environment types were more likely to provide health benefits than others. Vegetation patches such as grassland and tree canopy was not associated with reduced sudden unexpected deaths, but formal green spaces such as greenways and forests were [85]. People who spent time outdoor recalled greater mental restoration following visits to coastal locations and rural green space than urban green space [86]. Some environment types ("broadleaf woodland", "arable and horticulture", "improved grassland", "saltwater" and "coastal" environment) were positively associated with prevalence of good health among UK citizens [83]. The observed relationship between land cover types and BMI varied across age and gender. A positive relationship with lower BMI was found with high coverage of impervious surfaces among middle-aged adults and high forest coverage among young adult males. In other age and gender groups, the relationships were non-significant [76]. More rigorous studies, however, did not report significant findings. In a before-after study, the environment type of an outdoor walk did not have significant influence on emotional states of participants [22]. A sibling matched case-control analysis of Scottish mothers and their children (1991–2010) found that infant birth weight was associated with the quantity of natural space around the mother’s home, but was unrelated to specific types of natural space (parks, woods or open waters) [41].
**Table 3. Summary of findings.**

| Study * | Measure of Quality | Tool(s) Used to Assess Green Space Quality ** | Outcome | Outcome Assessment Tool ** | Direction of Effect # |
|---------|-------------------|---------------------------------------------|---------|---------------------------|-----------------------|
| Marselle, 2015 (n = 127) [22] | Environment types: natural and semi-natural places, green corridor, urban green space, farmland, urban public spaces, coastal, mixture | Self-reported | Positive & negative affect | PANAS scale | (o) |
| Stas, 2021 (n = 189) [79] | Vegetation species and cover types: trees vs. grass | GIS analysis | Severe tree pollen allergy event | Self-reported | (+) |
| Astell-Burt, 2020 (n = 109,688) [46] | Vegetation cover types: trees vs. grass | GIS analysis | Dementia: first medication prescription, first hospitalisation and deaths | Medical records | (+) |
| Astell-Burt, 2019 (n = 46,786) [45] | Vegetation cover types: trees, grass vs. low-lying vegetation | GIS analysis | Psychological stress; depression/anxiety; general health | K10-PDS; self-reported | (+) |
| Richardson, 2018 (n = 46,093) [41] | Natural space types: parks, woods, open waters | GIS analysis | Live births | Medical records | (+) |
| Astell-Burt, 2020 (n = 45,644) [48] | Vegetation cover types: trees vs. grass | GIS analysis | Memory complaints; self-rated memory | Semantic differential scale | (o) |
| Astell-Burt, 2021 (n = 45,644) | Vegetation cover types: trees vs. open grass | GIS analysis | CVD mortality, CVD events, AMI | Medical records | (o) |
| Gernes, 2019 (n = 478) [28] | Land cover diversity | GIS analysis | Outdoor allergen sensitisation; allergic rhinitis | Skin prick tests; clinically diagnosed | (–) |
| Donovan, 2018 (n = 39,108) [56] | Vegetation cover types | GIS analysis | Childhood asthma | Medical records | (+)(–) |
| Parmes, 2020 (n = 8063) [35] | Forest types: deciduous, coniferous vs. mixed | GIS analysis | Wheezing, asthma, allergic rhinitis, eczema | Parental reported | (–) |
| Jarvis, 2020 (n = 1,960,575) [64] | Land cover types: coniferous, deciduous, shrub, grass-herbs, water, buildings, paved surfaces | GIS analysis | General health, mental health, common mental disorders | Semantic differential scale | (+) |
| Nishigaki, 2020 (n = 126,878) [26] | Vegetation cover types: trees vs. grass | GIS analysis | Depression | SGD | (+) |
Table 3. Cont.

| Study * | Measure of Quality | Tool(s) Used to Assess Green Space Quality ** | Outcome | Outcome Assessment Tool ** | Direction of Effect # |
|---------|--------------------|-------------------------------------------|---------|---------------------------|----------------------|
| Wyles, 2019 (n = 4515) [86] | Environment types: coastal, rural green vs urban green | Self-reported | Restorativeness | Semantic differential scale (+) |
| Reid, 2017 (n = 1387) [74] | Vegetation cover types: trees vs. grass | GIS analysis | Perceived health | Semantic differential scale (+) |
| Jiang, 2020 (n = 212) [65] | Vegetation cover types: trees vs. low-lying vegetation | GIS analysis | General health; stress level | SF-12; PSS (+)(–) |
| Egorov, 2020 (n = 186) [59] | Vegetation cover types: trees vs. grass | GIS analysis | Allostatic load | Clinically measured (+) |
| Wheeler, 2015 (n = 31,672 LSOAs) [83] | Land cover diversity and environment types | SDI; GIS analysis | Health status | Semantic differential scale (+) |
| Aerts, 2020 (n = 1872 census tracts) [34] | Land cover types: gardens, forests vs. grassland | GIS analysis | Respiratory diseases | Medication sales (+) |
| Dennis, 2020 (n = 1673 LSOAs) [53] | Land cover diversity; vegetation cover types (ground, canopy vs. field-level) | SDI; GIS analysis | Chronic morbidity prevalence | CIDR (+) |
| Sander, 2017 (n = 546 census blocks) [76] | Land cover types: water, forest, canopy, impervious surfaces, and grass | GIS analysis | BMI | Self-measured height & weight (+) |
| Wu, 2017 (n = 543 districts) [33] | Vegetation cover types: forest, grassland, average tree canopy and near-road tree canopy | GIS analysis (50 m and 100 m buffers) | Autism | Medical records (+) |
| Wu, 2018 (n = 187 census tracts) [85] | Land cover types: water, open land, developed land, barren land, forest, shrub land, grassland, agriculture and wetland | GIS analysis (50 m and 100 m buffers) | Sudden unexpected deaths | Medical records (+) |
| Natural features (n = 15) | | | | |
| Marselle, 2015 (n = 127) [22] | Perceived naturalness; bird, butterfly, plants and trees biodiversity | Semantic differential scale, manual counting of species | Positive and negative affect | PANAS scale (–) |
| Astell-Burt, 2020 (n = 46,786) [47] | Tree coverage | GIS analysis | Diabetes, hypertension and cardiovascular diseases | Medical records (+) |
| Wyles, 2019 (n = 4515) [86] | Protected/designated area status | Assigned by national agency | Restorativeness | Semantic differential scale (+) |
| Study * | Measure of Quality | Tool(s) Used to Assess Green Space Quality ** | Outcome | Outcome Assessment Tool ** | Direction of Effect |
|---------|-------------------|---------------------------------------------|---------|----------------------------|---------------------|
| Leng, 2020 (n = 4155) [70] | Presence of evergreen trees | Environmental audits | Obesity, hypertension, diabetes, dyslipidaemia, stroke risk | Clinically measured BMI, blood pressure, blood glucose and lipid tests, stroke risk score card | (+) |
| Camargo, 2017 (n = 1392) [51] | Conditions of trees | Semantic differential scale | Quality of life | EUROHIS-QOL | (+) |
| Zhang, 2019 (n = 909) [24] | Tree density | POST | Quality of life | WHOQOL-BREF | (+) |
| Carter, 2014 (n = 440) [52] | Retention of green space and bushland | Semantic differential scale | Physical function | SF-36v2 | (o) |
| Tan, 2019 (n = 326) [23] | Tree density | Environmental audits | Physical functioning, physical role, bodily pain and emotional role | SF-12v2 | (o) |
| Pazhouhanfar, 2018 (n = 250) [73] | Tree and greening, flowers, sun, water, fresh air, and bird voice | Semantic differential scale | Mood ratings (relaxed/happy/excited/calm) | Semantic differential scale | (+) |
| Zhu, 2020 (n = 240) [89] | Sky index, soft/hard surface ratio, vertical vegetation coverage | Grid pixel calculation | Restorative effect | PRS | (+)(-) |
| Wood, 2018 (n = 128) [44] | Ecological study richness score: plant diversity, bird diversity, bee/butterfly diversity, number of habitats | Environmental audits; SDI | Restorative effect | Modified ART | (+) |
| Honold, 2016 (n = 32) [62] | Diversity of vegetation: façade, design, building shapes, vanishing points, angles | Semantic differential scale | Stress level | Hair cortisol level (immunoassay) | (o) |
| Wheeler, 2015 (n = 31,672 LSOAs) [83] | Bird species richness, freshwater quality indicator, density of protected area density | Bird occurrence atlas, routine surface water testing | Health status | Semantic differential scale | (+) |
| Mears, 2020 (n = 345 LSOAs) [42] | Bird biodiversity | Citizen science programme data | Poor general health | Semantic differential scale | (o) |
| Lai, 2019 (n = 174 zip codes) [69] | Pollen allergenicity of trees | Street tree census | Asthma prevalence | Medical records | (–) |
| Study * | Measure of Quality | Tool(s) Used to Assess Green Space Quality ** | Outcome | Outcome Assessment Tool ** | Direction of Effect \( 
eq \) |
|---------|-------------------|---------------------------------------------|---------|---------------------------|---------------------|
| Droomers, 2015  
\( (n = 48,132) \) [57] | Green intervention projects: reclaming vacant land, added recreational areas, paths and tracks, improved drainage, landscaping, maintenance | Construction and installation of new amenities | Health status | Semantic differential scale | (o) |
| Dobbinson, 2020  
\( (n = 1670) \) [55] | Refurbishments to existing amenities: playground equipment, quality walking paths, shade and shade-sail | Construction and installation of new amenities | Positive and negative affect | PANAS scale | (o) |
| Wood, 2017  
\( (n = 492) \) [84] | Park functions | POSDAT | Mental wellbeing | WEMWBS | (+) |
| McCarthy, 2017  
\( (n = 13,469) \) [31] | Playground quality: useability, cleanliness and maintenance, distinct areas for different age groups, colourful equipment, shade cover, benches, fence, separation from roads | Environmental audits | BMI | Clinically measured | (o) |
| Rundle, 2013  
\( (n = 13,102) \) [75] | Number of recreational facilities | Environmental audits | BMI | Clinically measured | (o) |
| Bojorquez, 2018  
\( (n = 2345) \) [40] | Park quality score: bathrooms, lighting, playground, etc. (9 items in total) | Environmental audits | Depressive symptoms | CES-D | (o) |
| Camargo, 2017  
\( (n = 1392) \) [51] | Walking paths conditions | Semantic differential scale | Quality of life | EUROHIS-QOL | (+) |
| Zhang, 2019  
\( (n = 909) \) [24] | Amenities: children’s play equipment, seating facilities, dog litter bags, water sources for dogs, drinking fountains, parking facilities, public transport, variety of permitted activities | POST | Quality of life | WHOQOL-BREF | (o) |
| Bai, 2013  
\( (n = 893) \) [50] | Availability of facilities of interest | Semantic differential scale | BMI | Self-measured height and weight | (o) |
| Pope, 2018  
\( (n = 578) \) [43] | Maintenance | Dichotomous survey question | Psychological distress | GHQ-12 | (o) |
| Tan, 2019  
\( (n = 326) \) [23] | Number of facilities and seats | Environmental audits | Physical functioning, physical role, bodily pain and emotional role | SF-12v2 | (o) |
| Study * | Measure of Quality | Tool(s) Used to Assess Green Space Quality ** | Outcome | Outcome Assessment Tool ** | Direction of Effect ≠ |
|-----------------|------------------|---------------------------------|---------------|-----------------------------|----------------------|
| Sugiyama, 2009  | Quality of access paths | Semantic differential scale         | Health status | No. of days with poor physical/mental health | SWLS (o) |
| (n = 271) [25]  |                  |                                 | Quality of life |                            | (o) |
| Mears, 2020     | Play facilities: playgrounds, games area, skate or bike parks | Environmental audits | BMI | Clinically measured | (o) |
| (n = 345 LSOAs) [32] |                  |                                 |               |                            | (o) |
| Ngom, 2016      | Green space functions | GIS databases                   | Coronary heart disease, cerebrovascular disease, heart failure, diabetes, hypertension | Medical records | (+) |
| (n = N/A) [71]  |                  |                                 |               |                            | (+) |
| Size (n = 11)   |                  |                                 |               |                            | (+) |
| Wood, 2017      | Park size         | GIS analysis (1.6 km buffer)     | Mental wellbeing | WEMWBS                  | (+) |
| (n = 492) [84]  |                  |                                 |               |                            | (+) |
| Stark, 2014     | Park size         | GIS analysis (805 m buffer)      | BMI           | Self-measured height and weight | (+) |
| (n = 44,282) [78] |                  |                                 |               |                            | (+) |
| Rundle, 2013    | Park size         | GIS analysis (805 m buffer)      | BMI           | Clinically measured        | (+) |
| (n = 13,102) [75] |                  |                                 |               |                            | (+) |
| Zhang, 2019     | Park area         | GIS analysis (400 m and 800 m buffers) | Quality of life | WHOQOL-BREF | (o) |
| (n = 909) [24]  |                  |                                 |               |                            | (o) |
| Tan, 2019       | Area              | Environmental audits             | Physical functioning, physical role, bodily pain and emotional role | SF-12v2 | (+) |
| (n = 326) [23]  |                  |                                 |               |                            | (+) |
| Kim, 2016       | Size of tree canopy | GIS analysis (805 m buffer)      | Quality of life | PedsQL | (+) |
| (n = 92) [30]   |                  |                                 |               |                            | (+) |
| Kim, 2014       | Size of tree canopy | GIS analysis (805 m buffer)      | BMI           | Clinically measured        | (+) |
| (n = 61) [29]   |                  |                                 |               |                            | (+) |
| Dennis, 2020    | Mean patch size   | GIS databases                   | Chronic morbidity prevalence | CIDR | (+) |
| (n = 1673 LSOAs) [53] |                  |                                 |               |                            | (+) |
| Wang, 2019      | Patch area        | GIS analysis (805 m buffer)      | All-cause, cardiovascular, chronic respiratory and neoplasm mortality | Medical records | (+) |
| (n = 369 census tracts) [82] |                  |                                 |               |                            | (+) |
| Study * | Measure of Quality | Tool(s) Used to Assess Green Space Quality ** | Outcome | Outcome Assessment Tool ** | Direction of Effect |
|---------|------------------|------------------------------------------|---------|----------------------------|---------------------|
| Mears, 2020 (n = 345 LSOAs) [32] | Garden size | GIS analysis (300 m buffer) | Obesity rate | Clinically measured BMI | (o) |
| Mears, 2020 (n = 345 LSOAs) [42] | Garden size | GIS analysis (300 m buffer) | Poor general health Depression and severe mental illnesses | Semantic differential scale Medical records | (+) |
| Kim, 2016 (n = 92) [30] | Pattern of green space patches: fragmentation, shape irregularity, isolation from other patches | GIS analysis (805 m buffer) | Quality of life | PedsQL | (+) |
| Kim, 2014 (n = 61) [29] | Connectedness | GIS analysis (805 m buffer) | BMI | Clinically measured | (+) |
| Kim, 2021 (n = 2301 census tracts) [67] | Size & dispersion of tree canopy patches | GIS analysis | Asthma emergency visits | Medical records | (+) |
| Sander, 2017 (n = 546 census blocks) [76] | Contiguity | GIS analysis | BMI | Self-measured height and weight | (+)(-) |
| Wang, 2019 (n = 369 census tracts) [82] | Pattern of green space patches: fragmentation, connectedness, aggregation, shape irregularity | GIS analysis (805 m buffer) | All-cause, cardiovascular, chronic respiratory and neoplasm mortality | Medical records | (+) |
| Tsai, 2016 (n = 52 MSAs) [80] | Pattern of green space patches: aggregation, contrast between patch types | GIS analysis | BMI | Self-reported height and weight | (+)(-) |
| Jaafari, 2020 (n = 87 hexagons) [63] | Pattern of green space patches: patch density, connectedness, shape irregularity | GIS analysis | Mortality of respiratory cancer diseases and respiratory diseases | Medical records | (+) |
| Shen, 2017 (n = 48 districts) [77] | Pattern of green space patches: fragmentation, aggregation, between-patch distances | GIS analysis | Respiratory mortality | Medical records | (+) |
| Safety (n = 6) | Perceived park crime | Dichotomous survey question | Mental health | Number of days with stress, depression, and emotion problems | (+) |
| Camargo, 2017 (n = 1392) [51] | Perceived safety of the way home | Semantic differential scale | Quality of life | EUROHIS-QOL 8-items | (+) |
| Study * | Measure of Quality | Tool(s) Used to Assess Green Space Quality ** | Outcome | Outcome Assessment Tool ** | Direction of Effect |
|---------|-------------------|--------------------------------------------|---------|---------------------------|--------------------|
| Bai, 2013 (n = 893) [50] | Safety | Semantic differential scale | BMI | Self-reported (o) | |
| Pope, 2018 (n = 578) [43] | Safety | Dichotomous survey question | Psychological distress | GHQ-12 (o) | |
| Tan, 2019 (n = 326) [23] | Perceived safety: reduced visibility, prospect of crime, presence of security guards, fear of falling, unwell feelings | Survey questionnaire (details unspecified) | Physical functioning, physical role, bodily pain and emotional role | SF-12v2 (+) | |
| Sugiyama, 2009 (n = 271) [25] | Safety: night-time safety, safety along surrounding paths, lack of crime | Semantic differential scale | Health status Quality of life | No. of days with poor physical/mental health SWLS (+) | |
| Stark, 2014 (n = 44,282) [78] | Cleanliness score | Parks Inspection Program audit tool | BMI | Self-measured height and weight (+) | |
| Rundle, 2013 (n = 13,102) [75] | Weeds, litter, glass, graffiti score and overall cleanliness score | Parks Inspection Program audit tool | BMI | Clinically measured (o) | |
| Zhang, 2019 (n = 909) [24] | Aesthetics: watered grass, no graffiti, no vandalism | POST | Quality of life | WHOQOL-BREF (o) | |
| Bai, 2013 (n = 893) [50] | Cleanliness | Semantic differential scale | BMI | Self-measured height and weight (o) | |
| Mears, 2020 (n = 345 LSOAs) [42] | Cleanliness | Environmental audits | Depression | Medical records (+) | |
| Herranz-Pascual, 2019 (n = 137) [61] | Soundscape characteristics | Semantic differential scale | Depression | Semantic differential scale (+) | |
| Sugiyama, 2009 (n = 271) [25] | Nuisance: dogs and dog foulings, presence of young people | Semantic differential scale | Health status Quality of life | No. of days with poor physical/mental health SWLS (o) | |
| Pazhouhanfar, 2018 (n = 250) [73] | Private environment | Semantic differential scale | Mood ratings (relaxed/happy/excited/calmmed) | Semantic differential scale (o) | |
| Study *          | Measure of Quality                                                                 | Tool(s) Used to Assess Green Space Quality ** | Outcome                                                                 | Outcome Assessment Tool ** | Direction of Effect |
|-----------------|-----------------------------------------------------------------------------------|-----------------------------------------------|-------------------------------------------------------------------------|----------------------------|---------------------|
| Perceived quality/Satisfaction with quality (n = 7) |                                                                                   |                                               |                                                                         |                            |                     |
| Putra, 2020 (n = 4969) [36] | Perceived quality by parents                                                      | Semantic differential scale                   | Prosocial behaviour                                                    | SDQ (+)                    |                     |
| Feng, 2018 (n = 3897) [39] | Perceived quality                                                                | Dichotomous survey question                   | Psychological distress; serious mental illnesses                        | K6-PDS (+)                 |                     |
| Feng, 2019 (n = 3843) [38] | Perceived quality                                                                | Semantic differential scale                   | BMI                                                                     | Self-measured height and weight (+) |                     |
| McEachan, 2018 (n = 805) [37] | Satisfaction with green space by parents                                         | Semantic differential scale                   | Total difficulties, internalising difficulties, externalising difficulties and prosocial behaviours | SDQ (+)                    |                     |
| Bai, 2013 (n = 893) [50]  | Attractiveness                                                                    | Semantic differential scale                   | BMI                                                                     | Self-measured height and weight (o) |                     |
| Pazhouhanfar, 2018 (n = 250) [73] | Attractiveness                                                                  | Semantic differential scale                   | Mood ratings (relaxed/happy/excited/calmmed)                           | Semantic differential scale (o) |                     |
| Jonker, 2014 (n = N/A)    | Satisfaction with quality                                                        | Semantic differential scale                   | Life expectancy and healthy life expectancy                             | National life table data (+) |                     |
| Combination of features (n = 13) |                                                                                   |                                               |                                                                         |                            |                     |
| Zhang, 2017 (n = 223) [87] | Perceived quality: recreational facilities, amenities, natural features, absent of civilities, accessibility, maintenance | Semantic differential scale                   | Neighbourhood satisfaction                                             | Semantic differential scale (+) |                     |
| Francis, 2012 (n = 911) [60] | Objective quality score: walking paths, shade, water features, irrigated lawn, birdlife, lighting, sporting facilities, playgrounds, type of surrounding roads, presence of nearby water Subjective quality score: atmosphere, comfort, safety, attractiveness and maintenance, variety of things to do, presence of adequate seating, public art, other people | POST (objective) Semantic differential scale (subjective) | Psychological distress                                              | K6-PDS (+)                 |                     |
| Bird, 2016 (n = 380) [27] | Park typology: team sports features, pool-oriented features, perceived safety, cycling-oriented features, play area features, walking-oriented, aesthetically pleasing, incivilities, infrequent park installations, schoolyard features | Author-developed typology, with principal component analysis | % truncal fat                                                         | X-ray absorptiometry (+) |                     |
Table 3. Cont.

| Study *                | Measure of Quality                                                                 | Tool(s) Used to Assess Green Space Quality ** | Outcome                                      | Outcome Assessment Tool ** | Direction of Effect #   |
|-----------------------|-----------------------------------------------------------------------------------|----------------------------------------------|----------------------------------------------|----------------------------|-------------------------|
| Kruize, 2020          | Objective quality score: general characteristics, facilities, traffic safety,     | Environmental audits/Semantic differential   | Mental wellbeing                             | MHI-5                      | (+)                     |
| (n = 3947) [68]       | infrastructure, sidewalk amenities, incivilities                                 | scale                                        |                                              |                            |                         |
| Vries, 2013           | Satisfaction with green space: quality, amount, maintenance, safety               | Semantic differential scale                  | Perceived general health; health complaints   | SF-36; acute health-related complaint checklist; MHI-5 | (+)                     |
| (n = 1641) [81]       |                                                                                   |                                              | and mental health                            |                            |                         |
| Dillen, 2012          | Green area quality: accessibility, maintenance, variation, naturalness,           | Environmental audits                          | Perceived general health; health complaints   | SF-36; acute health-related complaint checklist; MHI-5 | (+)                     |
| (n = 1553) [54]       | colourfulness, clear arrangement, shelter, absence of litter, safety, general     |                                              | and mental health                            |                            |                         |
| Carter, 2014          | Useability: in good conditions, well-equipped, including spaces to relax and        | Semantic differential scale                  | General health and vitality                   | SF-36v2                    | (+)                     |
| (n = 440) [52]        | socialise                                                                        |                                              |                                              |                            |                         |
| Dzhambov, 2018        | Perceived quality: safety, maintenance, aesthetic, suitability for sport and      | Semantic differential scale                  | Mental health                                | GHQ-12                     | (+)                     |
| (n = 399) [58]        | social interactions, biodiversity                                                 |                                              |                                              |                            |                         |
| Tan, 2019             | Aesthetics: colour, shape, diversity and seasonal variation of plants, maintenance,| Survey questionnaire (details unspecified)  | Physical functioning                         | SF-12v2                    | (o)                     |
| (n = 326) [23]        | proportions of soft surfaces                                                      |                                              |                                              |                            |                         |
| Sugiyama, 2009        | Pleasanness: adequacy for children to play, adequacy for adults to chat, variety | Semantic differential scale                  | Health status                                | No. of days with poor      |                         |
| (n = 271) [25]        | of activities to engage in, quality of trees and plants, facilities (toilet,     |                                              | Quality of life                              | physical/mental health     |                         |
| Zhang, 2019           | shelter)                                                                          | Semantic differential scale                  | Restorative effect                            | Semantic differential      | (+)                     |
| (n = 250) [88]        | Visual sensation: Variety of plants, richness of plants’ colour, plant light and |                                             |                                              | scale                      |                         |
|                       | shadow mottle, nice road texture, rich terrain, wide view, ornamental water      |                                              |                                              |                            |                         |
|                       | Auditory sensation: natural sound, sweet background music, happy people sounds     |                                              |                                              |                            |                         |
|                       | (singing or playing instruments), quiet background, no traffic noise              |                                              |                                              |                            |                         |
|                       | Tactile sensation: road material is comfortable and the foot feels good, strong    |                                              |                                              |                            |                         |
|                       | hydrophilic, seat is comfortable for sitting, comfortable grass for flat lay      |                                              |                                              |                            |                         |
| Study * | Measure of Quality | Tool(s) Used to Assess Green Space Quality ** | Outcome | Outcome Assessment Tool ** | Direction of Effect # |
|---------|------------------|--------------------------------------------|---------|---------------------------|----------------------|
| Mears, 2020 (n = 345 LSOAs) [32] | Quality * Size ≥ 2 ha * Predominantly natural feeling * Good or better quality ratings from council assessment, based on: signage; provision of facilities; maintenance of paths; safety; planting and plant management; and cleanliness | Environmental audits | BMI | Clinically measured | (+) |
| Mears, 2020 (n = 345 LSOAs) [42] | Quality * Size ≥ 2 ha * Predominantly natural feeling * Good or better quality ratings from council assessment, based on: signage; provision of facilities; maintenance of paths; safety; planting and plant management; and cleanliness | Environmental audits | Poor general health | Semantic differential scale | (o) |

Notes: Within each quality domain, studies were arranged by study design, and then by sample size. A full version of this table is available as Supplementary File S4. * Abbreviation: DA: dissemination areas; LSOA: lower layer Super output areas; MSA: metropolitan statistical areas ** AMI: acute myocardial infarction; ART: attention restoration theory; BMI: body mass index; CES-D: Center for Epidemiologic Studies-Depression; CIDR: comparative illness and disability ratio; CVD: cardiovascular diseases; EUROHIS-QOL-8: EUROHIS 8-item quality of life questionnaire; GDS: geriatric depression scale; GHQ-12: 12-item general health questionnaire; GIS: Geographic Information System; K10-PDS: Kessler ten-item psychological distress scale; K6-PDS: Kessler six-item psychological distress scale; MHI-5: 5-item mental health inventory; PANAS: positive and negative affect schedule; PedsQL: paediatric quality of life inventory; POST: Public Open Space Tool; POSDAT: Public Open Space Desktop Auditing Tool; PRS: perceived restorativeness scale; PSS: perceived stress scale; SDI: Shannon’s diversity index; SDQ: strengths and difficulties questionnaire; SF-8: eight-item short form survey; SF-12: 12-item short form survey; SF-12v2: short form 12 item (version 2); SF-36: 36-item short form survey; SF-36v2: short form 36 item (version 2); SWLS: satisfaction with life scale; WEMWBS: Warwick Edinburgh mental well-being scale; WHOQOL-BREF: World Health Organization quality-of-life scale. ≠ (+) Some evidence of protective associations; (–) some evidence of risk associations; (o) no significant associations observed.
Similarly, the type of vegetation within green space potentially modulated its health benefits. There was consistent evidence of forests being a protective factor for obstructive airway diseases [28,34], cardiovascular diseases [49], allostatic overload [59], psychological distress and general health [45,65,74] while grassland and herbaceous vegetation were not. On the other hand, some studies showed superior benefits of shrubs and grass compared to trees in improving mental health [64] or severe allergy [79]. In low-diversity areas, certain vegetation types presented higher risks for asthma or other allergic conditions, typically non-native shrubs [56] or coniferous trees [35]. No difference in benefits between vegetation types was observed in studies of memory and dementia [46,48], depression and anxiety [26,45]. In one study, all vegetation types were shown to be protective against autism, which was potentially driven by their shared function of buffering against traffic noise and air pollution buffering [33].

3.5.2. Natural Features

There was one before-after study, one cohort study, ten cross-sectional studies and three ecological studies under this domain. Natural features refer to characteristics of vegetation, animals, water bodies, and the overall naturalness of green space. Trees, flowers and fresh air [73] conferred restorative benefits to park visitors, with differential effects between genders. The higher density of trees among park vegetation was associated with lower rates of cardiovascular conditions [47,70] and a higher quality of life [24,51], but not overall general health [23]. The presence of dense shrubs, which implied lower security and safety, reduced the restorative benefits of parks [89]. Green spaces perceived as being more “natural”, such as protected areas or bushlands, provided greater benefits on mental restoration [86] and physical health [52,83]. A combination of habitat, plant, bird and insect biodiversity exhibited restorative effects, but each biodiversity component alone did not [22,42,44]. Interestingly, neither quantity or diversity of neighbourhood vegetation alone was significant predictor of stress levels, but vegetation diversity could modify the relationship between vegetation quantity and stress levels [62].

Certain green space characteristics were potentially associated with health risks. Streetscape with tree species of high allergenicity was associated with an increase in local asthma hospitalisation rates in vulnerable populations [69]. Freshwater quality was identified as an indicator of poor health status [83].

3.5.3. Infrastructure and Amenities

There were nine cross-sectional studies, two quasi-experimental studies, one prospective cohort study and two ecological studies under this domain. Infrastructure and amenities refer to the availability of facilities for various purposes (recreation, resting, socialisation, etc.), the quality of paths within and leading to green space, and general maintenance. Park facilities did not reduce rates of depression [40], BMI [31,32,50,75] nor general health status of park users [23,24]. High maintenance was not associated with lower psychological distress [43] or BMI [50]. However, parks that function as recreational or sports venues may provide some cardiovascular and mental health benefits [71,84]. Mixed results were reported on the relationship between walking paths’ conditions and quality of life [25,51]. A natural experiment was conducted in disadvantaged suburbs of Melbourne, Australia, tracking psychological wellbeing of park visitors for 3 years after adding refurbishments (playground equipment, walking paths and shade) to selected parks. When compared to control parks, park refurbishments did not improve emotional states of park visitors [55]. Similarly, in the Netherlands, neighbourhoods that implemented interventions to increase accessibility and useability of green space did not see an improved general health compared to control neighbourhoods [57].

3.5.4. Size

There was one prospective cohort study, six cross-sectional studies and four ecological studies and under this domain. Ten studies used spatial analysis to measure green patch
size. Most studies found evidence for health benefits of larger green space for a wide range of outcomes: BMI [29,75], cardiovascular mortality [82], chronic morbidities [53], depression [42], general health status [23] and quality of life [30]. In a prospective cohort study in Perth (Australia), where residents were followed up after settling into a new neighbourhood, the increases in numbers of small parks, district parks and regional parks were each positively associated with mental wellbeing, but not the mid-sized local and neighbourhood open spaces [84]. However, some studies reported inconclusive evidence for these health benefits [24,32,78].

3.5.5. Shape, Pattern and Connectivity

There were six ecological studies and two cross-sectional studies under this domain. While all studies used spatial analysis to quantify green space patterns, six studies combined health data at the spatial block level [63,67,76,77,80,82] while others conducted regression analyses using individualised data [29,30]. All studies reported positive correlation between indices measuring the shapes and distribution patterns of green patches and a wide range of outcomes, including BMI [29,76], paediatric quality of life [30], respiratory health [63,67,77] and all-cause mortality [82]. The indices include the fragmentation index (higher values indicate more fragmented green space areas), mean area of greens space (higher values indicate averagely larger green space areas), connectedness index (higher values indicate more connection between individual green spaces), aggregation/isolation index (higher values indicate more clustering of individual green spaces), shape irregularity index (higher values means more irregular shape of each green space, as opposed to round/oval shape). When stratified by gender, age and retirement status, differential benefits were observed for female and younger users [76].

3.5.6. Safety

There were six cross-sectional studies under this domain. The safety of green space was associated with better quality of life [23,25,51], reduced psychological distress [43] but did not have significant effects on BMI [50] of residents. In a mediation analysis, park crimes reduced the benefits of parks on mental health [72].

3.5.7. Cleanliness and Absence of Incivilities

There were three cross-sectional studies and one ecological study under this domain. Park cleanliness, either ranked by park visitors or assessed by trained auditors, was associated with lower rate of depression [42]. Evidence was inconclusive for BMI [50,78] or quality of life [24].

3.5.8. Peacefulness

There were three cross-sectional studies under this domain. A lower level of “nuisance” (defined as presence of dogs, dog fouling, or young people) was not correlated with better life satisfaction nor physical health among the elderly [25]. Park users did not consider a private environment in the park important in improving their mood states [73]. On the other hand, soundscapes in parks triggered positive feelings and reduced stress [61].

3.5.9. Perceived Quality/Satisfaction with Quality

There were four nested cohort studies, two cross-sectional studies, and one ecological study under this domain. In these studies, participants were asked to rank their perceived quality or aesthetics of green spaces, without a priori definition of factors to be considered. All studies examining “perceived quality” demonstrate positive association of green space’s perceived quality with health. Women living near good-quality local parks had lower rates of postpartum psychological distress or serious mental illnesses [39]. The effect on postpartum weight gain was less clear, with significant benefits only observed in areas with high vegetation coverage (≥40%) [38]. Parents’ satisfaction with green space was also linked to improved prosocial behaviour of their children [36,37]. Analysis of the
Netherlands’ population data found a modest increase in life expectancy among residents living near high-quality green spaces [66]. However, perceived aesthetics of parks was neither a predictor of mood states [73] nor BMI [50].

3.5.10. Combination of Features

There were one quasi-experimental study, two cohort studies, eight cross-sectional studies and two ecological studies under this domain. These studies use a mix of features from the previous domains to evaluate park quality. Detailed definitions of these composite scores were outlined in Table 3.

Five studies determined objective quality based on audits by trained assessors [32,42,54,60,68] while others asked participants to rank quality based on a set of criteria [23,25,52,58,60,68,81,87,88]. Park quality had positive benefits on reducing BMI and truncal fats in young children [27,32]. Evidence on benefits for general health were mixed [8,23,25,42,52,54,81]. Zhang et al. introduced a concept of multi-sensory experience, suggesting that visual, auditory and tactile sensation, provided by different park features, all contributed to the restorative effects of parks [88].

Three studies investigated both objectively measured and the perceived quality of green spaces, and compared their effects on health. When comparing two neighbourhoods with different socioeconomic status, the residents’ perceived quality of a green space statistically mediated the relationship between its objective quality and neighbourhood satisfaction, but did not have any direct effect of wellbeing [87]. Only objective quality reduced psychosocial distress (K6-PDS questionnaire) in one study [60] while only perceived quality improved mental wellbeing (MHI-5 questionnaire) in another study [68].

4. Discussion

Overall, our review demonstrates evidence of health benefits associated with a wide range of green space qualities. Increasing research interest in green space qualities was demonstrated (Figure 2) and this aligns with rising interest in urban greening to counter the health and climate impacts of urbanisation [6]. The COVID-19 pandemic may also have amplified attention on this topic from academics and policymakers, as communities in many countries have flocked to green spaces as a means of coping with lockdowns and socioeconomic disruption [92,93]. After excluding results with a study quality assessment score under 50 (N = 32), evidence showed consistent positive associations with health with the green space qualities we classified as “environment types”, “natural features”, “shape and connectivity”, and “objective quality scores”. Limited evidence was found on the health benefits of improving infrastructure or amenities in green spaces. Research gaps were identified for the following green space qualities: peacefulness, safety and absence of incivilities; needs-specific or culture-appropriate amenities, and soundscape characteristics.

4.1. Green Space Qualities

The most commonly assessed qualities of green spaces were the environment types of the natural space, as well as vegetation types and other natural characteristics. Our review shows that some environment types were linked to positive health outcomes more than others [41,83,86]. Health benefits were observed when the environment type facilitated age- and gender-appropriate physical activities. For example, middle-aged adults group preferred built facilities with paved paths for exercising whereas young adults prefer forested areas with unobstructed grounds for athletic, adventurous activities such as hiking, trail-running or mountain biking [76,82]. Therefore, preserving diversity in land cover types (e.g., structured versus natural) may be a potential option to enhance health benefits of green spaces, especially in dense urban areas with limited options for expansion. Moreover, green space designs might be optimized for health through tailoring to local community profiles, to bring people together and to enable them to do what they find nourishing. This requires consultation and it is likely that certain qualities may be a source of conflicting views. For example, accommodating for birds in green spaces may be viewed positively.
for their provision of restorative soundscapes and an enhanced feeling of connectedness with nature, but also negatively due to the timing of their sounds, impacts on property (e.g., droppings) and occasional swooping that may create a lack of felt safety [94].

Evidence indicated that some vegetation types may be more beneficial towards particular health outcomes than others. Tree canopy and forests were more consistently associated with better cardiovascular and respiratory health than grassland [47,59,67,79]. A reason may be that trees permit and promote restoration while also providing shade that helps to activate walking and active transportation (particularly in hot climates), whereas grass and shrubs might not convey the same range and levels of benefit [76]. Moreover, because of their foliage, evidence indicates that forests have the capacity to intercept airborne pollutants and buffer against traffic noise, alleviating oxidative stress and reducing risks of atherosclerotic diseases [95]. On the other hand, shrubs may impede visibility and reduce levels of felt safety, while large areas of open grass may reduce walkability (especially if it is walled or fenced-off, as can be the case for private green spaces like golf courses) [74,76,89]. Importantly, this may reflect an interaction between vegetation type and other contextual factors, such as levels of crime, nearby land-use and transport infrastructure. Further research that examines potential contingencies of association between vegetation types and health outcomes within the context of other land-uses is warranted.

Interestingly, many studies in the facilities/amenities domain show no statistically significant associations with physical or mental health, despite evidence that some of these qualities are associated with physical activity [90]. This might be because different types of facilities may result in different forms of behaviour, some of which may instead promote sedentary forms of leisure (e.g., seating) or detract from the perceived ‘naturalness’ appealed by certain park users (e.g., some sports facilities that use synthetic materials) [96]. Moreover, some studies may log the availability facilities but not their condition and usability. For instance, access to areas of parks and particular buildings may be difficult for people with functional limitations, while there may also be cultural or social factors that influence whether a particular facility is considered accessible [97].

Some qualities have a small evidence base, such as safety, tranquility or absence of incivilities. Most of this evidence focused on psychological wellbeing or quality of life using Likert-type rankings or the number of unwell days. Future studies on these aspects will benefit from using robust, validated questionnaires featured in other quality domains, such as MHI-5, PRS or PANAS [22,55,68,89]. Moreover, perceived safety of public spaces can be influenced by neighbourhood characteristics and social vulnerabilities, which need to be accounted for in future studies.

Some quality domains were not featured among the included studies. Availability of needs-specific amenities, such as for people living with particular disabilities, may encourage more inclusive park usage and increase the potential to reduce health inequity [3,98]. Tailoring park amenities and features to the local communities, such as instructions in multiple languages, accommodation (and celebration) of cultural traditions and rituals, etc., may be particularly important in multi-cultural neighborhoods [99,100]. One study examined the feelings evoked by soundscapes [61], but the constituents of soundscapes that provide therapeutic effects, such as sounds of nature, human activities or traffic noise, were not elucidated. Types of bird songs were previously studied, but as sound clips rather than actual exposure inside parks [89].

### 4.2. Health Outcomes

Physical health is the most commonly assessed set of health outcomes. Most studies showed evidence of potential benefits for anthropometric measures (BMI and obesity) and respiratory health (allergic diseases). Understandably, there are established frameworks explaining how green spaces reduce obesity via promoting physical activities [96,101] and protects against respiratory diseases via regulating temperature and air pollution [77]. Only 7 out of 34 studies on physical health examined associations with cardiovascular diseases.
Based on existing evidence, higher quality green space may reduce cardiovascular mortality and incidence of cardiometabolic diseases [47,70,71]. However, evidence for associations with specific cardiovascular diseases was small. Consistent evidence from this review indicated a range of probable mental health benefits linked with various green space qualities. This aligns with existing conceptual frameworks, which suggest green spaces can confer mental health benefits via reducing stressor exposures and replenishing mental resources for coping [3].

Although the evidence base is substantial for physical and psychological health outcomes, there is granularity in the quality of outcome measurement tools. For physical health, a number of studies relied on general health questionnaires such as SF-12 and SF-36. These have a low administrative burden and good internal validity [91], but responses may differ among age, education or ethnicity subgroups [102], which may explain conflicting findings among these studies. For mental health, some studies used self-ranked Likert-type questions, which lacked reliability and consistency compared to validated questionnaires like the MHI-5, K6-PDS or CED-S. A potential approach for future studies is to use quantifiable biological measure to validate subjective questionnaires, such as hair cortisol levels as a proxy for stress [62].

Few studies investigated child development. This could be the focus of future studies, as evidence suggests possible health benefits linked to reduced maternal stress during pregnancy [33] and opportunities for play and socialisation during time spent in green spaces [36,37].

Certain outcomes were not featured in the included studies. Vegetation types and structure influence their ability to regulate pollution and local climate, and thus will have differential effects on heat-related health risks [103]. Postpartum distress was examined [39], but the effects on antenatal depression or neonatal outcomes were not investigated. This is an important topic, as the greenness of the environment was associated with reduced risks of low birth weight and preterm delivery [104].

4.3. Quality of Study Designs

Overall, the level of evidence certainty for health benefits of green space quality remains low.

This is due to two important reasons. Firstly, there was a high degree of heterogeneity in study designs, green space and green space quality definitions, and outcome measurements. Some studies use factor analysis to derive the qualities, which make it difficult to find out the definitions behind the derived terms, especially when the survey questionnaires were not included [40,52]. Many studies ask participants to rank certain qualities or report health outcomes on a Likert scale-type questions, without defining the quality being surveyed for the participants. These potentially introduce bias in response and are a major limitation among studies in this topic. Even with GIS methods, which are deemed more reliable and reproducible in quantifying green space exposure, variations in proximity radius and buffer zones make it difficult to compare results across studies.

Secondly, none of the included studies were randomised trials, which resulted in a lower overall quality of evidence.

Only 6/10 domains featured evidence from longitudinal cohort studies or interventional studies (before-after and quasi-experimental studies), namely the domains of environment types, natural features, infrastructures and amenities, size, perceived quality, and combination of features. Within each domain, cross-sectional and ecological studies often accounted for more than half of the evidence base. The prevalence of observational studies is characteristic of environmental health research, which faces intrinsic logistical and ethical challenges in designing rigorously controlled trials [105]. Nonetheless, observational studies have their limitations [106]. Cross-sectional surveys do not permit inference of causation. In our review, many cross-sectional surveys used convenience sampling, which could introduce selection bias due to seasonal weather, site of surveys or time of day. Longitudinal studies can factor in temporal relationship between green space exposure
and health outcomes. They also enabled adjustment for factors that can influence health outcomes, such as demographic characteristics, measures of poverty and deprivation, and socioeconomic status (income, education and employment) (Table 1). However, many cohort studies in our review were nested in longitudinal health surveys that did not routinely collect data on green space quality, and only achieved so via a cross-sectional survey or geospatial analysis [36,38,39], again making it impossible to establish temporal causation. Although ecological studies echo the principles of environmental health policies, their generalizability is limited. By assuming that green space exposure applies uniformly to all individuals within a census tract or administrative area, these studies do not control for individual health and preference, and thus may lead to incorrect inferences ("ecological fallacy"). The use of multiple databases in GIS analysis, featured in many of our studies, also raises the possibility of spatial autocorrelation and mismatched data sources, etc. [34,83].

Before-after studies and quasi-experiments are pragmatic designs that support causal inference by establishing a clear temporal relationship between exposure and outcomes and controlling for confounding factors. They provide real world effectiveness of complex interventions, and are thus compatible with population policies [107].

It is important to note that, although longitudinal cohort studies and interventional studies were less prevalent, they have methodological strengths that cross-sectional and ecological studies do not. In our review, limiting analysis to these studies did not change the overall conclusion across all quality domains.

4.4. Future Directions

Innovative trial designs have been featured in this review, namely quasi-experimental studies using controlled parks or neighbourhoods [55,57]. In addition, controlled intervention design had been used in forest therapy trials, which allowed for robust pre-post measurements of cardiovascular outcomes such as blood pressure, heart rate and oxygen saturation [108]. However, high logistical demands often limited the duration of these trials and precluded studies of long-term (child development) or high-risk outcomes (childbirth, cardiovascular events). Studies nested in cohort follow-up studies [28,36,37,41,49,60,84] are a promising approach by leveraging on well-designed longitudinal studies with annual follow ups, comprehensive baseline data collection, and large sample sizes for robust statistical power. Where randomisation is not possible, study data could be analysed using interrupted times-series analysis, which adjusts for some effects of context and individual health variations over time [69].

Satellite imagery and GIS should still be part of the essential toolbox for green space quality studies, as long as GIS data is linked to patient-level data instead of being aggregated at ecological unit levels. GIS has proven useful in combining cartographical datasets, identifying and classifying land cover types. Recent advances in geospatial big data also introduced new approaches to assessing green space exposure, such as eye-level exposure (street view imagery) as opposed to overhead exposure (satellite imagery) [109]. In addition, GIS technology has enabled new indices for quantifying green space size, shape and connectivity [30,82]. By virtue of defined formulae, these indices were reproducible and reliable, and could be used in various statistical analyses.

Our findings showed that perceived green space quality, even without any judging criteria, can predict health benefits [36,37,39,66]. This is an important consideration, given that spatial environmental indicators (size, greenness, aesthetics) do not always corresponded with user perceptions [110]. Therefore, it is advisable for future studies to measure both perceived and objective quality when assessing health benefits. This approach has the dual benefits of ensuring internal validity of the subjective quality measurement, while accounting for any mediating effect of user perceptions on the objective quality [60,68].

Several studies used a composite quality score that aggregated across several domains (e.g., Public Open Space Tool). Although a composite score approach can reflect the complexity of green space quality, coverage can be restricted to attributes related to facilities, safety and cleanliness, which are shown in our review to have little association with
health so far. RECITAL, the latest quality assessment index developed to address this gap, incorporates other quality domains such as suitability for activities, land cover types and biodiversity [111], which generally aligns with our classification. This index can be stratified into single-item or sub-section scores, allowing researchers to investigate specific aspects of quality, which is a shortcoming commonly associated with aggregated scales. Comprehensive indices such as this should be explored in future studies. Last but not least, there is a need for a new index that aggregates qualities across networks of multiple green spaces of various shapes and attributes. This may be particularly salient within higher density contexts, where multiple smaller green spaces exist with each containing a small number of qualities, but larger ones that may incorporate many more qualities do not.

4.5. Strengths and Limitations

The strength of our review is its breadth of coverage, as we formulated our search strategy intentionally to capture across a range of health outcomes, potential qualities and green space types. Our review is the first to capture the diverse evidence conducted in this area and map them into domains of quality. Nonetheless, our review was not without limitations. As the concept of green space quality was not well-defined, we took a holistic approach but our review could still potentially miss out relevant studies that did not use conventional descriptors of quality. Our review only included studies written in English, and in view of more emerging research on park designs from China in recent years [112], publication bias due to exclusion of non-English articles was possible. Although our review was structured based on established protocols, the screening process was subjected to some degree of subjectivity due to a lack of standardized definitions in this topic.

5. Conclusions

Research on green space quality and health has increased in volume, especially since 2016. A high degree of heterogeneity was observed in study design, and the definitions of quality and outcomes measured. Environment types, vegetation types, and the size and connectivity of green spaces, were associated with physical and mental health outcomes, with differences by age and gender. The associations indicative of health benefits were more consistent in populations with more tree canopy, but not more grassland. Qualities such as safety, cleanliness and aesthetics tended to be investigated with weaker study designs. Both objective and subjective quality demonstrated positive effects on health outcomes. There is a need for more experimental studies or well-designed prospective studies that incorporate longitudinal measures of green space qualities and outcome-appropriate confounders. Green space indices should account for form, pattern, networks, and both objective and perceived qualities.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph182111028/s1, Supplementary File S1: Search strategy; Supplementary File S2: Quality assessment of included studies; Supplementary File S3: List of excluded studies from full-text review. Supplementary file S4: Summary of findings (expanded).

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