Biological Psychiatry: GOS

Review

The Relationship Between Greenspace Exposure and Psychopathology Symptoms: A Systematic Review

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ABSTRACT

Greenspace exposure is associated with psychological benefits. In this systematic review, we summarized and critically evaluated the literature on the relationship between greenspace exposure (i.e., objective and subjective assessments of interactions with nature) and psychopathology incidence and symptom severity in those with and without a clinical diagnosis. A secondary aim of our review was to examine potential interactions between greenspace exposure and urban environmental features (e.g., pollution, population density) associated with poorer mental health. We identified 40 studies published between January 1, 1981, and July 31, 2020, from PubMed and PsycINFO electronic database search. Although heterogeneous in assessments of greenspace exposure and psychopathology symptom domain, the majority of cross-sectional and longitudinal evidence found that objectively assessed greenspace exposure (e.g., satellite measures of greenery) was related to less severe symptoms and lower incidence of psychopathology in children (e.g., attention-deficit/hyperactivity disorder symptoms) and adults (e.g., depression symptoms). In addition, five studies that assessed urban environmental features suggest that greenspace exposure may show a net positive relationship with psychopathology over and above the absence of urban features. We discuss limitations of the literature and future directions, including more mechanistic work to delineate the potential cognitive, affective, and behavioral factors that may contribute to the beneficial relationship between greenspace exposure and psychological health.

https://doi.org/10.1016/j.bpsgos.2022.01.004

Exposure to greenspace (i.e., nature) is commonly regarded as pleasant and restorative. Gardening, hiking, and having indoor plants are associated with higher hedonic well-being and social connectedness (1–8). Living close to parks or having vegetation around one's home is associated with general mental well-being and may have cumulative benefits over the course of one's life (9–11). Greenspace exposure may have direct effects on our mental health; theories such as stress reduction theory argue that because human brains evolved in a natural environment, we are more at ease in greenspaces (12). In turn, evidence suggests that green and natural spaces have restorative properties (13,14). Greenspaces may also provide indirect benefits, such as more opportunities to engage in adaptive behaviors (e.g., social interactions, physical activity). It is also likely that people with better psychological health are more likely to use or access green areas. However, evidence that urban environments (i.e., nonrural areas with low greenspace density/prevalence) and their accompanying factors (e.g., pollution) are associated with stress (15,16), loneliness (17), negative affect (18), and a higher prevalence of mental health concerns compared with rural environments (19,20) suggests that our environment affects our mental state just as much as (if not more than) our mental states influence the environments we inhabit.

An open question is whether the psychological benefits of greenspace exposure extend to relief from psychopathology symptoms. Such experiences are associated with mental health concerns such as depression and are increasingly prevalent, with approximately 1 in 4 adults experiencing a mental health diagnosis at any given time (21,22). Mental health diagnoses account for the highest rates of global disability, with loss of productivity costs averaging $310 billion worldwide (23). In addition, more than half of the global population lives in a metropolitan or urban area (24), with pre–COVID-19 pandemic evidence suggesting that urbanization is steadily increasing (25). As more people migrate to urban spaces—environments that may have a detrimental impact on one's well-being—it is paramount to understand the relationship between greenspace exposure and mental health concerns. While previous reviews have focused on the relationship between greenspace exposure and overall mental well-being, including citing individual studies that assess psychopathology (5,26,27), no review to date has aimed to specifically assess the relationship between greenspace exposure and psychopathology symptom incidence and severity across diagnoses and populations.

In this systematic review, we aimed to synthesize and critically evaluate the existing literature on the relationship between greenspace exposure and psychopathology across

ISSN: 2667-1743

children and adults. We included studies that used validated measurements of symptoms and/or clinician-diagnosed disorders, whereas past reviews included a mixture of validated symptom measures and measures of general mental well-being. We also included a broad definition of greenspace exposure, encompassing studies that used objective (e.g., satellite measures of green coverage in a given area) and/or subjective (e.g., qualitative experience of greenery) assessments. Our secondary aim was to evaluate studies that examined potential interactions with greenspace exposure and urban environmental features that are often associated with negative mental health effects. Because greenspace is inversely related to features of urbanicity, we were interested in whether the available evidence supports the hypothesis that greenspace exposure has a net effect on psychopathology severity and incidence over and above the negative effects of urban environmental features.

METHODS

Search Strategy and Identification

Studies that met predetermined criteria were systematically reviewed using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines (28) (see Figure 1). In addition to "greenspace," "NDVI" was also included as a potential keyword. NDVI refers to the Normalized Difference Vegetation Index, a satellite measure of the amount of green reflected off of vegetation and a common measure of greenspace density used in environmental research (29). NDVI does not account for snow coverage or leaf color changes in autumn (29). See the Supplement for full details on search strategy, identification, and article review process.

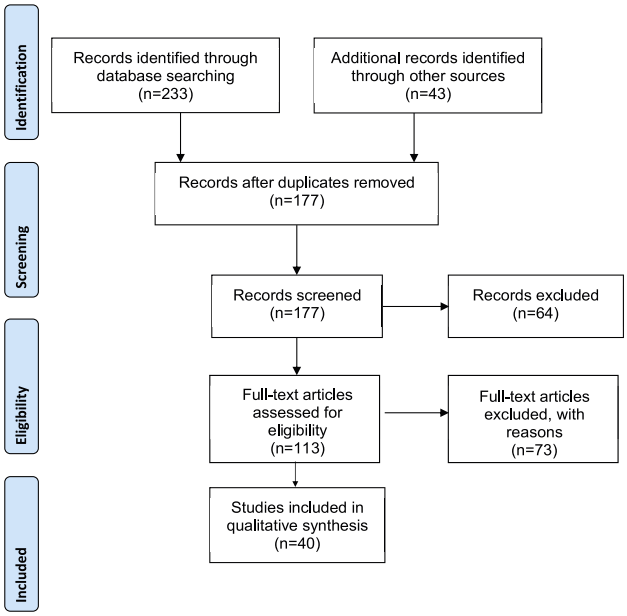

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) search and selection diagram.

Inclusion and Exclusion Criteria

Studies were included when they assessed 1) an objective and/or subjective metric of greenspace (see Figure 2 for operational definitions) and 2) its relationship to a) a mental health diagnosis, as defined by ICD-10 (30) or DSM-5 (31) criteria, or b) psychopathology symptoms, defined as those strongly associated with or required for a formal diagnosis of a psychological disorder (e.g., low mood for major depressive disorder), as assessed by a validated measure of such symptoms [e.g., Patient Health Questionnaire (32)]. Assessments of behaviors such as self-harm and suicidality were included because they are significantly associated with a range of psychological disorders and represent a transdiagnostic indicator of more severe psychological distress and impairment (33–39). Studies were excluded if they only assessed general mental health, well-being, or psychological distress [e.g., using scales such as the General Health Questionnaire (40)] or if they only assessed broad feelings of restoration or connection to nature as an outcome variable but did not include a validated measure of psychopathology symptoms.

In addition, we noted whether a study examined urban environmental features in addition to greenspace exposure. Urban environmental features were operationalized as variables unique to urban environments and commonly associated with stress or psychopathology (e.g., pollution, population density). This definition was in line with other work measuring urbanicity and the negative effects of urban environments (41).

RESULTS

Study Selection

See Figure 1 for PRISMA diagram of study search and selection process and the Supplement for a detailed description of the study selection process. In total, 40 studies met the inclusion criteria and were included in this review.

Study Characteristics

See Table 1 for a summary of all included studies and measures of psychopathology symptoms. The majority of studies took place in Europe (n = 20) and North America (n = 15). Overall, 15 studies assessed psychopathology symptoms in children, and 25 studies assessed these symptoms in adults. A total of 27 studies were cross-sectional in nature, with 12 longitudinal studies and one study that experimentally manipulated time spent in greenspace. Studies varied in assessments of psychopathology: 11 studies measured incidence of specific mental health diagnoses, 10 measured psychopathology symptoms in individuals with mental health diagnoses, and 20 measured psychopathology symptoms in the general population. The majority of studies included objective assessments of greenspace exposure, including 1) green coverage around residences or work/school as captured by objective measures of surrounding greenspace (i.e., NDVI, tree coverage), 2) access to greenspace, and/or 3) proximity to greenspace (e.g., Euclidean distance, minutes to walk to nearest park). Within these categories, some studies further separated greenspace by type (e.g., public park, garden) or used national databases of land use. Studies that included subjective measures assessed factors such as qualitative

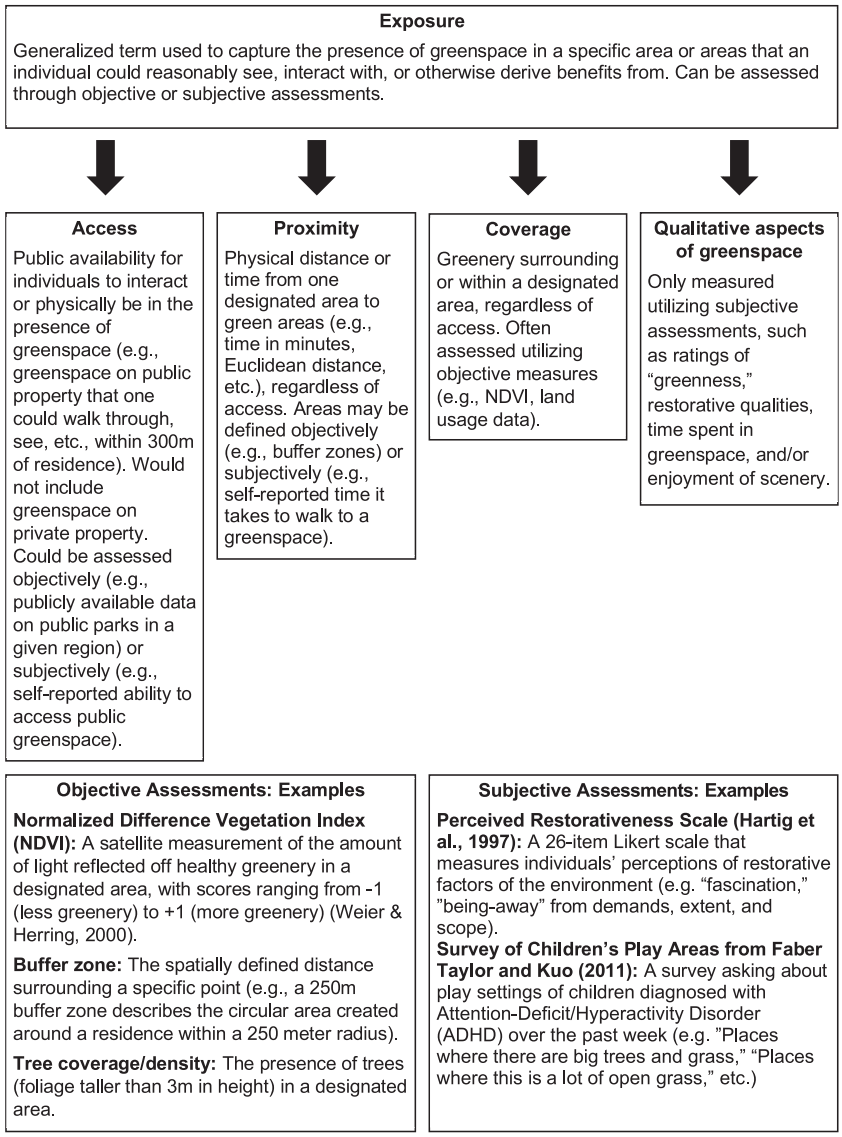

Figure 2. Operational definitions of types of interactions with greenspace. ADHD, attention-deficit/hyperactivity disorder; NDVI, Normalized Difference Vegetation Index. [Subjective assessments examples are from (47,86).]

greenness of one's environment or specific interactions with greenspace, such as time spent in green areas. In addition to greenspace exposure, 27 studies measured negative features of urban environments, and 14 of these examined their relationship to both greenspace and psychopathology symptoms. See Figure 2 for operational definitions of common greenspace exposure assessment methods and Table 2 for a summary of specific methods of assessing greenspace per study included in this review.

Attention-Deficit/Hyperactivity Disorder and Internalizing and Externalizing Behaviors in Children

A total of 14 studies examined psychopathology symptoms in children, focusing on symptoms of attention-deficit/hyperactivity disorder (ADHD), internalizing behaviors (symptoms associated with internal experiences of children, e.g., depression, social withdrawal), and externalizing behaviors (behaviors directed toward others, e.g., aggression, bullying) (42). Internalizing and externalizing behaviors tend to overlap and are associated with later, more specific psychopathology (42–45).

Attention-Deficit/Hyperactivity Disorder. Objective greenspace exposure (e.g., NDVI) was negatively associated with incidence of an ADHD diagnosis (46) and symptoms of ADHD in formally diagnosed children (13,47,48). For example, Amoly *et al.* (13) found that both subjective (time spent in greenspace) and objective (greenspace coverage in neighborhood) assessments of greenspace were associated with less severe ADHD symptoms in diagnosed children. Similar relationships were found when assessing proximity to greenspace in neighborhoods (46) and exposure to greenspace in outdoor play areas (13).

Table 1. Descriptions of Studies Selected for Formal Review

Study	Location	Psychopathology Symptom or Diagnosis	*N*	Age, Years	% Male	% White	Psychopathology Measures	Coverage, Proximity, Access, Other	Urban Variables
Amoly *et al.*, 2014 (13)	Spain	Attention-deficit/hyperactivity disorder	2111	7–10	50.30%	NR	Strengths and Difficulties Questionnaire	Coverage	
Andrusaityte *et al.*, 2020 (51)	Lithuania	Internalizing or externalizing concerns (behavioral problems)	1489	4–6	49.6%	NR	Strengths and Difficulties Questionnaire	Coverage, proximity	Tobacco smoking during pregnancy and exposure to pollutants
Balseviciene *et al.*, 2014 (52)	Lithuania	Internalizing or externalizing concerns (behavioral problems)	1468	21–59	0%	100%	Strengths and Difficulties Questionnaire	Coverage, proximity	
Banay *et al.*, 2019 (58)	USA (11 states)	Depression	38,947	54–91	0%	95%	Diagnosis or history of antidepressant use	Coverage	Air pollution, population density
Berman *et al.*, 2012 (64)	USA	Depression	20	Mean = 26	40%	NR	Diagnosis	Asked to walk for 50 min in greenspace or an urban environment	
Beyer *et al.*, 2014 (65)	USA	Depression and/or anxiety	2479	21–74	NR	NR	Depression Anxiety Stress Scale	Coverage	Population density, urbanicity
Bezold *et al.*, 2018 (53)	USA	Depression	8374	9–14	42%	93%	McKnight Risk Factor Scale, Center for Epidemiological Studies–Depression	Coverage	Air pollution, population density
Bezold *et al.*, 2018 (54)	USA	Depression	9385	12–18	41%	90%	McKnight Risk Factor Scale	Coverage	Population density
Bos *et al.*, 2016 (75)	Netherlands	Depression and/or anxiety	4924	Mean = 47	35%	NR	Depression Anxiety Stress Scale	Coverage	
Brown *et al.*, 2018 (59)	USA	Depression	249,405	Over 65	NR	NR	Diagnosis	Coverage	
Dzhambov *et al.*, 2018 (66)	Bulgaria	Depression and/or anxiety	109	Mean = 21	55%	NR	General Health Questionnaire−12	Coverage	Air pollution, residential noise
Dzhambov *et al.*, 2019 (67)	Bulgaria	Depression and/or anxiety	529	18–35	33.60%	NR	General Anxiety Disorder-7, Patient Health Questionnaire-9	Coverage, subjective measures	

Table 1. Continued

Study	Location	Psychopathology Symptom or Diagnosis	*N*	Age, Years	% Male	% White	Psychopathology Measures	Coverage, Proximity, Access, Other	Urban Variables
Engemann *et al.*, 2019 (81)	Europe	Psychological disorder (intellectual disability, borderline personality disorder, specific personality disorders, anorexia nervosa, eating disorders, obsessive-compulsive disorder, anxiety and somatic disorders, single and recurrent depression, recurrent depressive disorder [MDD], bipolar disorder, mood disorders, schizophrenia, schizophrenia spectrum disorders, cannabis use disorder, alcohol use disorder, substance abuse, any psychiatric disorder)	NR	13–19	NR	NR		Coverage (lifetime)	Urbanicity
Engemann *et al.*, 2020 (79)	Europe	Schizophrenia	943,027	NR	NR	NR	Diagnosis	Coverage	Air pollution, urbanization
Faber Taylor and Kuo, 2011 (47)	USA	Attention-deficit/hyperactivity disorder	421	5–18	80%	NR	Parent-rated severity of symptoms	Coverage	Concrete coverage and tall buildings
Gariepy *et al.*, 2015 (68)	Canada	Depression	1298	NR	NR	NR	Patient Health Questionnaire-9	Coverage	Neighborhood deprivation
Gascon *et al.*, 2018 (62)	Spain	Depression and/or anxiety	958	44–74	36.10%	NR	Self-reported diagnosis, history of antianxiety or antidepression medication	Coverage, access	Air pollution
Henson *et al.*, 2020 (78)	USA	Schizophrenia	63	30 (HC); 37.75 (SZ)	50% (HC); 51.4% (SZ)	11.5% (HC); 54.3% (SZ)	Ecologic momentary assessment; diagnosis	Coverage	Population density
Jarvis *et al.*, 2020 (76)	Canada	Depression and/or anxiety	1,960,575	12 and up	48.40%	50.70%	Canadian community health survey, diagnosis	Coverage, Access	Urbanicity
Kim and Kim, 2017 (74)	South Korea	Depression	23,139	Over 19	44.2%	NR	"Have you ever felt sadness or despair in two consecutive weeks in the past year?"	Coverage	Air pollution
Lee *et al.*, 2019 (55)	South Korea	Internalizing or externalizing concerns (aggression)	1817	7–17	NR	NR	Child Behavior Checklist	Coverage	Air pollution
Liu *et al.*, 2019 (69)	China	Depression	20,533	Mean = 44.81	47%	53%	Center for Epidemiological Studies–Depression	Coverage	Urbanicity, population density

Table 1. Continued

Study	Location	Psychopathology Symptom or Diagnosis	*N*	Age, Years	% Male	% White	Psychopathology Measures	Coverage, Proximity, Access, Other	Urban Variables
Markevych *et al.*, 2014 (48)	Germany	Attention-deficit/hyperactivity disorder	1932	10	51.4%	NR	Strengths and Difficulties Questionnaire	Proximity, access	
Markevych *et al.*, 2018 (46)	Germany	Attention-deficit/hyperactivity disorder	66,823	10–14	51%	NR	Diagnosis	Coverage	Average air pollution, population density
Marselle *et al.*, 2013 (70)	England	Depression	1258	55 and older	38%	NR	Major Depressive Inventory, Perceived Stress Scale, Positive and Negative Affect Schedule	Coverage, access	
Mears *et al.*, 2020 (80)	UK	Depression	293	NR	NR	NR	Diagnosis	Coverage, access, cleanliness	Address density, deprivation, smoking rates
Mueller *et al.*, 2019 (56)	England and Wales	Internalizing or externalizing concerns (emotional and behavioral resilience)	3683	10–15	50.60%	85.40%	Strengths and Difficulties Questionnaire	Coverage	Air pollution, neighborhood deprivation, urbanicity or rurality
Nutsford *et al.*, 2014 (77)	New Zealand	Depression/mood disorders, anxiety disorders	NR	15 and older	NR	NR	Received secondary mental health treatment, at least one pharmaceutical for anxiety/mood disorder treatment, or had three or more laboratory tests for lithium over the year	Access, coverage, proximity	Area deprivation
Orstad *et al.*, 2020 (11)	USA	Depression	3652	18 and older	41%	44%	Self-reported poor mental health days or diagnosis, problems with emotions	Access, proximity	
Polling *et al.*, 2019 (82)	England	Self-harm	8327	15 and older	39%	55.2%	Hospital admission due to self-harm	Coverage	Deprivation, urbanicity
Pun *et al.*, 2018 (71)	USA	Depression and/or anxiety	4118	57–85	NR	NR	Hospital Anxiety and Depression Scale, Center for Epidemiological Studies–Depression	Coverage	Air pollution, proximity to highway, urbanicity (land use)
Richardson *et al.*, 2017 (50)	Scotland	Attention-deficit/hyperactivity disorder (hyperactivity and emotional problems)	2909	3–7	51%	NR	Strengths and Difficulties Questionnaire	Coverage	

Table 1. Continued

Study	Location	Psychopathology Symptom or Diagnosis	*N*	Age, Years	% Male	% White	Psychopathology Measures	Coverage, Proximity, Access, Other	Urban Variables
Rugel *et al.*, 2019 (63)	Canada	Depression	1,930,480	15 and older	47.60%	49.90%	Canadian Community Health Survey-Mental Health, Mental Health Continuum Short Form, Kessler Psychological Distress Scale-10	Coverage, proximity, access	
Sarkar *et al.*, 2018 (60)	UK	Depression	94,879	37–73	46%	NR	Patient Health Questionnaire-9	Coverage, access	Air pollution and movement density
Song *et al.*, 2019 (72)	South Korea	Depression	65,128	Over 19	46.50%	NR	Center for Epidemiological Studies–Depression	Coverage, access	Deprivation index
Srugo *et al.*, 2019 (83)	Canada	Suicidality	6313	11–20	43.20%	59.7%	Kessler Psychological Distress Scale-6, suicidal ideation, suicidal action	Coverage	Walkability
Triguero-Mas *et al.*, 2015 (73)	Spain	Depression and/or anxiety	8793	NR	49.94%	NR	General Health Questionnaire-12; perceived depression and anxiety; visits to mental health care professional intake of medication	Coverage, access	Degree of urbanization
Van Aart *et al.*, 2018 (49)	Belgium	Depression, anxiety, attention-deficit/hyperactivity disorder, internalizing and externalizing concerns	172	9–15	50.90%	NR	Strengths and Difficulties Questionnaire	Coverage, proximity	Proximity to traffic, air pollution, and noise
Younan *et al.*, 2016 (57)	USA	Internalizing or externalizing concerns (aggression)	1287	NR	NR	NR	Child Behavior Checklist	Coverage	Proximity to freeways and highways, traffic density
Zock *et al.*, 2018 (61)	Netherlands	Depression and/or anxiety	4450	18–65	49.10%	NR	Diagnosis	Coverage	Degree of urbanization, air pollution, noise, and morbidity

HC, healthy control; MDD, major depressive disorder; NR, not reported; SZ, schizophrenia.

Table 2. Summary of Greenspace Exposure Methods Across Studies

Study	Coverage	Access	Proximity	Qualitative Aspects of Greenspace	Other	Objective Measures of Green Coverage	Subjective Measures
Amoly *et al.*, 2014 (13)	X	X	X	X		NDVI, spatial scale 100, 250, 500 m	
Andrusaityte *et al.*, 2020 (51)	X		X	X		NDVI, spatial scale 100, 300, 500 m	Hours spent in greenspace, <5 hours/week (low) and >5 hours/week (high)
Balseviciene *et al.*, 2014 (52)	X		X			NDVI, spatial scale 300 m	
Banay *et al.*, 2019 (58)	X					NDVI, spatial scale 250, 1250 m	
Berman *et al.*, 2012 (64)				X	Intervention (50-min walk in either green or urban setting)		
Beyer *et al.*, 2014 (65)	X					NDVI, spatial scale 1000 m	
Bezold *et al.*, 2018 (53)	X					NDVI, spatial scale 250, 1250 m	
Bezold *et al.*, 2018 (54)	X				Tree canopy coverage	NDVI	
Bos *et al.*, 2016 (75)	X				Land use (e.g., urban green, agricultural green, and natural green)	GIS, spatial scale 1, 3 km	
Brown *et al.*, 2018 (59)	X					NDVI, spatial scale 15 × 15 m	
Dzhambov *et al.*, 2018 (66)	X			X		NDVI, spatial scale 100, 300, 500 m	PRS
Dzhambov *et al.*, 2019 (67)	X			X		Tree coverage; NDVI, spatial scale 100 m, 300 m, 500 m, 1 km	PRS
Engemann *et al.*, 2019 (81)	X	X		X		NDVI, spatial scale 210 × 210 m, 330 × 330 m, 570 × 570 m, and 930 × 930 m	
Engemann *et al.*, 2020 (79)	X				Land cover (agricultural, artificial surfaces, near-natural greenspace, and blue space)	CORINE; NDVI spatial scale 100 × 100 m, 500 × 500 m, 1000 × 1000 m, 3000 × 3000 m	
Faber Taylor and Kuo, 2011 (47)	X	X		X	Type of greenspace in play areas (e.g., big trees, wild place, barnyard)		Parent questionnaire on child behavior
Gariepy *et al.*, 2015 (68)	X					NDVI, spatial scale 500, 1000, 1500 m	
Gascon *et al.*, 2018 (62)	X	X		X	Type of greenspace (e.g., agricultural green, forest green, and urban green)	Map of landcover in Catalonia; NDVI, spatial scale 30 × 30 m	
Henson *et al.*, 2020 (78)	X					NDVI, spatial scale 30 m; areas with NDVI values ≥ 0.5 were considered "high greenspace" while areas ≤0.5 were considered "low greenspace"	

Table 2. Continued

Study	Coverage	Access	Proximity	Qualitative Aspects of Greenspace	Other	Objective Measures of Green Coverage	Subjective Measures
Jarvis *et al.*, 2020 (76)	X	X		X	Type of greenspace (e.g., coniferous, deciduous, shrub, grass)	2014 Rapid Eye satellite imagery and 2008–2015 LiDAR data, spatial scale 150, 500, 1000 m	
Kim and Kim, 2017 (74)	X	X			Greenness area type (i.e., green facilities area, general green area, riverside green area)	2013 Seoul Metropolitan data on park and green areas	
Lee *et al.*, 2019 (55)	X					MSAVI; NDVI, spatial scale 1600 m	
Liu *et al.*, 2019 (69)	X			X		China Labor Force Dynamics Survey, 2016	
Markevych *et al.*, 2014 (48)	X					NDVI, spatial scale 250 m	
Markevych *et al.*, 2018 (46)		X	X		Land use	LGN7 2012; spatial scale 25 × 25 m	Parent questionnaire on child behavior
Marselle *et al.*, 2013 (70)	X	X		X	Walk environment type (natural and seminatural places, green corridor, farmland, parks and gardens, urban public space, coastal, amenity greenspace, allotments, community gardens, urban farms, outdoor sports facilities, or an "other" write-in category)		
Mears *et al.*, 2020 (80)	X	X		X	Public greenspace cleanliness	Tree density; LSOA, spatial scale 300 m	Sheffield City Council's 2008 assessment of accessible green and open space provision
Mueller *et al.*, 2019 (56)	X				Type of greenspace (e.g., domestic garden, greenspace)	MEDIx; CORINE; GLUD	
Nutsford *et al.*, 2014 (77)	X	X	X		Distance to usable green space, distance to total green space, proportion of usable green space within 300 m, proportion of total green space within 300 m, proportion of usable green space within 3 km, proportion of total green space within 3 km	Greenspaces ≥ 500 m^2 were included	
Orstad *et al.*, 2020 (11)			X	X	Self-reported minutes to walk to park		

Table 2. Continued

Study	Coverage	Access	Proximity	Qualitative Aspects of Greenspace	Other	Objective Measures of Green Coverage	Subjective Measures
Polling *et al.*, 2019 (82)	X					Percentage of greenspace coverage collected from London Department of Communities and Local Government Data	
Pun *et al.*, 2018 (71)	X	X	X	X	Retrospective rating of how much time spent in natural outdoor environments as a child	NDVI, spatial scale 30 × 30 m	Perceived amount of current exposure to natural outdoor environments, measured across duration and frequency of visits to natural areas; satisfaction with natural outdoor environment (quality, amount, maintenance, and safety); importance of natural areas
Richardson *et al.*, 2017 (50)	X	X	X	X	Type of greenspace (e.g., vegetation, private garden)	Scotland's greenspace map 500 m	Community greenness
Rugel *et al.*, 2019 (63)	X	X	X	X		Enhanced Vegetation Index; Natural Space Index; NDVI, spatial scale 50, 100, 250, 400 m	
Sarkar *et al.*, 2018 (60)	X	X		X	Street-level accessibility, terrain	NDVI, spatial scale 500 m	
Song *et al.*, 2019 (72)	X				Land use (e.g., forests, farmland)	Korea Forest Service; NDVI, spatial scale 250 × 250 m	
Srugo *et al.*, 2019 (83)	X					NDVI, spatial scale 500, 1000 m	
Triguero-Mas *et al.*, 2015 (73)	X	X				NDVI, spatial scale 30 × 30 m	
Van Aart *et al.*, 2018 (49)			X	X	Type of greenspace (e.g., seminatural, forested, and agricultural areas)	CORINE, spatial scale 100, 300, 500, 1000, 3000 m, 4000, 5000 m	
Younan *et al.*, 2016 (57)	X					NDVI, spatial scale 250, 350, 500, 1000 m	
Zock *et al.*, 2018 (61)	X					LGN7 2012, spatial scale 25 × 25 m	

GIS, Geographical Information System; GLUD, Generalised Land Use Database; LSOA, lower-layer super output area; MSAVI, Modified Soil-Adjusted Vegetation Index; NDVI, Normalized Difference Vegetation Index; PRS, Perceived Restorativeness Scale.

hree studies assessed ADHD symptoms in children without a formal diagnosis. In a longitudinal study, Van Aart *et al.* (49) found that more coverage and closer proximity to greenspace surrounding residences were associated with less hyperactivity, anxiety, and mood symptoms in healthy children at baseline. Follow-up measures 5 years later indicated that greenspace was associated with higher scores of happiness (see Table 1), but significant associations were not found for other psychopathology symptoms (49). An additional study found that fewer symptoms of inattention and hyperactivity were correlated with exposure to urban greenspace around the child's residence in healthy male children. However, the same study found no relationship between proximity to forests or other surrounding greenspace and participant mental health (47). Conversely, in a longitudinal study, Richardson *et al.* (50) found that healthy children with access to gardens had significantly higher scores of hyperactivity, while other greenspace metrics (e.g., green coverage or proximity to nearby parks) did not have any significant relationships with ADHD symptoms.

Internalizing and Externalizing Behaviors. Seven studies examined the relationship between NDVI (as an assessment of neighborhood greenspace coverage) with externalizing and internalizing behaviors in large samples of children from the general population (51–57). One study additionally measured time children spent in parks (51). Two studies found that more green coverage was associated with less severe internalizing and externalizing symptoms in healthy children. This included one longitudinal study that found less severe aggressive behavior in twins and triplets at risk for developing antisocial personality disorder (57) and another that found overall lower scores of psychopathology (55). One study found a relationship between greenspace exposure and less severe symptoms of depression, but only at high population density (53). Alternatively, Bezold *et al.* (54) found that more greenspace exposure over multiple years was associated with less severe depression symptoms in middle school, but not high school, students. Three studies did not find a relationship between greenspace exposure and children's behavior (51,52,56); however, Balseviciene *et al.* (52) found that children living within closer proximity to city parks reported fewer total difficulties, hyperactivity symptoms, peer problems, and conduct problems, but only for children whose mothers did not attend college.

Summary. Few studies have examined greenspace exposure and its relationship to childhood psychopathology. Greenspace coverage appears to be associated with less severe symptoms of ADHD in children with a formal diagnosis; however, it is unclear whether greenspace exposure is related to less severe symptoms of hyperactivity and inattention in healthy children. Greenspace exposure may be associated with less severe externalizing and internalizing symptoms in children in the general population. A few individual studies suggest that the relationship between greenspace exposure and psychopathology symptoms in children may be moderated by sociodemographic factors (e.g., population density), although these findings require replication.

Depression and Anxiety

A total of 16 studies assessed depression symptoms and greenspace exposure in adults by assessing 1) incidence of major depressive disorder (MDD) in specific areas, 2) depressive symptoms in individuals with MDD, or 3) depressive symptoms in the general population. Of these 16 studies, 7 studies also assessed anxiety, either separately from depression symptoms or through a single anxiety/depression symptom construct.

Depression. In the studies that examined formally diagnosed MDD, four of six studies found that more greenspace exposure was associated with a lower incidence of MDD (58–61), including one in a longitudinal study (58). The remaining two studies found no relationship between greenspace coverage and depression prevalence, although these studies found that greenspace access was associated with lower prevalence of depression-related disorders (62,63). Three additional studies found that greenspace exposure was related to fewer symptoms and better mental health in those with MDD (11,59,64). Berman *et al.* (64) were the only researchers to experimentally manipulate time spent in greenspace, where participants with MDD were primed to ruminate and randomized to either walk through nature or through an urban environment with minimal greenspace. In the natural condition, the participants reported less negative and more positive affect than in the urban condition, although the researchers did not assess changes in depression symptoms. Sarkar *et al.* (60) also found a negative association between greenspace exposure and MDD symptoms, except in areas with high terrain variability (e.g., rockiness, hilliness); more terrain variability was associated with higher odds of MDD, even in areas with the highest green coverage. This study also found that the negative association between greenspace exposure and MDD symptoms was stronger in women and in participants younger than 60 years (regardless of sex) (60).

A total of 11 studies examined depression symptoms in the general population (63,65–74). Of these, 9 studies assessed greenspace exposure through objective measures, and some further divided greenspace based on features such as farmland (70) or tree coverage (65). Seven of eight of these studies found that greenspace exposure was related to less severe depression symptoms (65–69,72,73). Dzhambov *et al.* (67) found that objective (NDVI) and subjective (perceived greenness of neighborhood) measures of greenspace were associated with less severe symptoms of depression in healthy adults. Two studies also found that increased social connection and ratings of environmental restorative qualities mediated the effects of greenspace exposure on depression symptoms (63,66). In other words, greenspace exposure was only related to less severe depression symptoms when participants reported increased social connection and/or that their environment was restorative. Four studies found no relationship between greenspace exposure and symptoms of depression in adults within the general population (63,70,71,74). Pun *et al.* (71) found that greenspace exposure was only related to less severe depression symptoms in White participants and in

participants with high socioeconomic status who were also physically active.

Two studies examined urban greenspace exposure and its relationship to depression symptoms in the general population. Song *et al.* (72) found that urban greenspace exposure was related to less severe depression symptoms, while Marselle *et al.* (70) did not find a relationship between this type of greenspace and depression. Urban greenspace was operationalized differently by each study: Song *et al.* (72) looked at green coverage in seven major Korean cities, whereas Marselle *et al.* (70) defined specific walking environments as urban greenspaces in accordance with local planning policy guidelines in the United Kingdom (70). In both cases, specific effort was made to identify greenspaces in cities as qualitatively different from those in rural or nonurban areas.

Anxiety. Five studies examined either incidence of anxiety and depressive disorders (61,62) or anxiety and depression symptoms in the general population (65,67,71), with conflicting results. Gascon *et al.* (62) did not find a relationship between greenspace coverage and self-reported anxiety disorders, although they did find a negative association between greenspace coverage and benzodiazepine use. Zock *et al.* (61) found that more greenspace coverage around residences was associated with lower incidence of both anxiety and depression-related disorders based on electronic health records. In the general population, two studies found that greenspace coverage was associated with fewer symptoms of depression and anxiety (65,67); however, Pun *et al.* (71) found that symptoms of anxiety alone were not related to greenspace coverage after controlling for demographic factors.

Four studies reported anxiety and depression together as a single construct [e.g., "anxiety/depression disorders" (73,75–77)]. Of these four studies, three studies found that more greenspace coverage and access to greenspace surrounding residences were associated with lower incidence of historical clinician-diagnosed anxiety/depression disorder (73,76,77). Jarvis *et al.* (76) found decreased odds of mental health concerns in men in areas with more green coverage. Conversely, Bos *et al.* (75) found that higher greenspace coverage was associated with more psychopathology (including anxiety/depression disorders) in specific age groups but less psychopathology in women generally and of specific age groups.

Summary. Greenspace exposure appears to be associated with less severe symptoms of depression in both those with and those without MDD and that odds of depressive disorders appear to decrease in areas with more green coverage. There are fewer studies that examine the relationship between greenspace exposure and anxiety symptoms, and these had conflicting results. No study to date has examined the relationship between greenspace exposure and anxiety disorder incidence or symptom severity separately from depression.

Psychosis Spectrum Disorders

Three studies examined the relationship between psychosis spectrum disorder symptoms and prevalence and greenspace exposure. Henson *et al.* (78) found that people with schizophrenia had less exposure (encounters and time spent) to greenspace in their daily lives compared with a healthy comparison group. However, greenspace exposure was related to less severe symptoms of anxiety, depression, and psychosis for participants with schizophrenia who had high greenspace exposure (NDVI $\geq$ 0.5) over a 3-month period (78). Engemann *et al.* (79) found that more greenspace exposure during the first 10 years of life was related to less incidence of psychosis spectrum disorders in adulthood. In contrast, Mears *et al.* (80) did not find a significant relationship between access to public greenspace and rates of serious mental illness (i.e., bipolar disorder and psychosis spectrum disorders), using a combination of self-reported mental health and diagnosis history drawn from national databases in England.

Incidence of Multiple Psychological Disorders

One longitudinal study looked at incidence of multiple psychiatric disorders over 10 years collected from national databases in Denmark (Table 2) (81). More greenspace exposure from birth to 10 years of age (assessed annually by NDVI) was associated with lower odds of being diagnosed with any psychiatric disorder, except intellectual disability and schizoaffective disorder, in a dose-response pattern (81). These results are consistent with previously reviewed literature showing a relationship between greenspace exposure and lower incidence of depression (58–61), ADHD (48), anxiety (61), and schizophrenia (79). Neither age nor parental socioeconomic status was significantly related to risk of developing a disorder; however, a small effect of consecutive years of greenspace exposure was found in lowering risk.

Self-harm and Suicidality

Two studies examined the relationships between self-harm and suicidality with greenspace exposure in the general population. Polling *et al.* (82) found that regions with lower percentages of greenspace coverage (operationalized from local government data) and areas with a higher population density were associated with lower rates of inpatient hospital admission for a first incidence of self-harm across four hospitals in South-East London. Srugo *et al.* (83) examined self-reported suicidal ideation, suicide attempts, and general mental health in healthy children and emerging adults (ages 11–20) in Canada and found no relationship with greenspace coverage around the participants' schoolgrounds.

Greenspace, Urbanization, and Psychopathology

We examined studies that assessed features of urban environments in addition to greenspace exposure on their impact on psychopathology symptoms (see Table 1). The most identified urban features were air pollution, population density, deprivation (i.e., low employment, low education, low-paying jobs), or urbanicity. Urbanicity was defined differently across studies, although it commonly combined two overlapping features of urban environments as one construct [e.g., population density and commuting area (65)]. Although nearly half of our reviewed studies included some measure of negative impact from urban environments, far fewer measured the

Table 3. Summary of Main Findings and Limitations From Current Evidence on Associations Between Greenspace Exposure and Psychopathology Symptoms

Main Findings	Limitations
Greenspace exposure largely correlated with less severe/lower incidence of psychopathology symptoms	Reliance on cross-sectional methods
Objective measures of greenspace were consistently defined as satellite measures (e.g., Normalized Difference Vegetative Index)	Few intervention/experimental studies
Positive subjective experience of greenspace associated with less psychopathology	Lack of standardization of assessing psychopathology symptoms, making comparing effect sizes difficult
Attention-deficit/hyperactivity disorder most frequently measured in children and fewer symptoms correlated to higher greenspace exposure	Studies conducted primarily in North America or Europe
Depression most frequently measured in adults and fewer symptoms correlated to higher greenspace exposure	Limited reports of racial identity of participants (12 of 40)
Studies measuring urbanicity and greenspace found positive buffer effect of greenspace against negative features of urban environments	Few studies on high-risk populations (e.g., psychosis [n = 3] and suicidality/self-harm [n = 2])
	Limited range of psychological disorders (e.g., absence of studies assessing posttraumatic stress disorder, obsessive-compulsive disorder, anxiety disorders separate from depression)
	Lack of comparisons of similar symptom clusters between adults and children or longitudinal studies to assess how the relationship between psychopathology and greenspace exposure may change across the lifespan
	In studies measuring prevalence of psychological disorder diagnoses, general health measures (e.g., General Health Questionnaire) were often used rather than symptom-specific measures (e.g., Beck Depression Inventory)
	Few studies using subjective measures of greenspace exposure
	Potential publication bias toward publishing significant (e.g., significant relationship between greenspace exposure and psychopathology) vs. nonsignificant effects

combined effects of greenspace exposure and urbanicity on psychopathology symptoms. A total of 13 studies measured urban variables but failed to examine whether such variables interacted with the relationship between greenspace exposure and psychopathology symptoms (47,51,58,61,65,68,71,72,74,76,78,79,82).

Of the studies that examined potential interactions between urban environmental features and greenspace exposure, findings suggest that greenspace may mitigate harmful effects of urban features on psychopathology. Five studies found that greenspace exposure was related to a lower incidence of psychiatric diagnoses for multiple disorders (81), incidence of depressive/anxiety disorders (77), incidence of ADHD in children (48), and symptoms of depression and anxiety (60,65), over and above the negative impact of urban features. In addition, two studies that looked at population density (53,54) found that children living in highly populated areas with more green coverage experienced less severe symptoms of depression than those living in areas with lower population density and a comparable amount of green coverage. Beyer *et al.* (65) also found that higher racial segregation in neighborhoods was associated with higher rates of symptoms of depression, anxiety, and stress, regardless of greenspace exposure. Some studies found that urban variables mediated the relationship between greenspace exposure and incidence of anxiety medication use (62), depression symptoms in the general population (49,69), and aggression in healthy children (55). In some of these, the relationship between greenspace exposure and psychopathology disappeared when urban variables were accounted for (55,62); however, other studies maintained this association, but the effect size was affected when accounting for urban variables (49,69). Other studies found no influence of urban features on the relationship between greenspace and depression (73), symptoms of depression and anxiety in the general population (66), or incidence of self-harm hospital admissions (82).

DISCUSSION

Overall, 40 studies examined the relationship between greenspace exposure and psychopathology in those with and without diagnosed mental health concerns. Methods varied widely, including in greenspace exposure metrics (e.g., objective vs. subjective), psychopathology symptoms and assessments (e.g., incidence vs. severity), and sample sizes (e.g., large-scale epidemiological studies vs. experimental studies). The majority of research was cross-sectional in nature. Despite this variability, the evidence largely suggests that greenspace exposure is associated with less severe and/or decreased prevalence of psychopathology. This was most consistently observed in ADHD in children and depression in adults. Unfortunately, there was no overlap in disorders explored in adults and children, making comparisons across the lifespan difficult. For a summary of main findings and limitations of the literature, see Table 3.

In addition, we assessed studies that examined the relationship between greenspace exposure and urban environmental features that are commonly associated with poorer psychological health. Of the 40 studies we reviewed, 14 examined these potential interactions; researchers overall found a benefit of greenspace exposure on psychopathology symptoms over the negative impact of urbanicity. A strength across these studies was that researchers did not operationalize urban environments as simply an absence of greenspace or greenspace as simply an absence of urban features; rather than treating these features as simply opposites of one another, they treated urban features and greenspace as potentially independent constructs. This allowed researchers

to make claims regarding the potential net psychological benefits of greenspace beyond simply being an absence of negative urban features. However, the majority of studies did not assess urban environmental features at all, did not examine interactions between urban features and greenspace, or failed to include multiple indices of urbanicity. Further understanding of whether greenspace and urban features truly have counteractive effects remains an important area of research.

Clarifying the roles of greenspace exposure and urbanicity on psychopathology has far-reaching implications for city planning, urban development, and the mental health field at large. If greenspace truly buffers the negative mental health effects of urban environmental features, even in small doses, this would suggest that green recreational areas are crucial for urban population health. Given what we already know about the negative impact of urbanicity on psychopathology in children (84) and adults (19,85), research in these areas remains critical. In addition, the potential role that greenspace exposure may play in promoting psychological recovery within existing psychosocial treatments remains an open question. This work could greatly affect clinicians' ability to deliver more personalized, low-cost treatments to mitigate negative effects of socioenvironmental experiences.

There remains a dearth of experimental evidence to clarify what mechanisms, if any, help explain the relationship between psychopathology and greenspace exposure. However, there is some indirect support that 1) greenspaces may provide opportunities for mental health–promoting behaviors and 2) subjective experience of greenery may promote psychological health. A few studies that found a positive effect of greenspace exposure on depression symptoms found that increased physical (11) or social activity (63,66) mediated these relationships. Although our review included very few intervention and longitudinal studies, of those included, positive associations between greenspace exposure and psychopathology were found (49,53,64,66). One notable longitudinal study by Engemann *et al.* (81) found a dose-response relationship between greenspace exposure and decreased likelihood of psychopathology symptoms or mental health diagnoses. Because only a few studies suggest that psychopathology symptoms may improve following greenspace exposure, future research is necessary to clarify whether a causal relationship exists.

In addition, of the 40 reviewed studies, eight included some assessment of qualitative, subjective experience, with three of these studies finding a significant correlation between positive qualitative experiences of green areas and reduced psychopathology (49,62,63). Positive qualitative ratings of greenspace were associated with reduced symptoms of anxiety and depression, indicating that perceiving the environment as sufficiently green or restorative may have major downstream effects on psychopathology. In other words, the presence of greenery on its own may influence affective experiences (64). Findings from these studies are in line with theories that discuss the evolutionary role of nature in adaptive processing of the environment (12). Thus, greenspaces may be psychologically beneficial through mechanisms that influence cognitive and affective processes (e.g., stress reduction) that, in turn, affect psychopathology. Future research is necessary to extend this work to better understand how, when, and why greenspace exposure may be related to better psychological health.

Greenspace access is another critical area for understanding the relationship between greenspace exposure and psychopathology. Although few studies examined specific types of greenspace (e.g., trees vs. grass), the studies that did found that less accessible greenspaces, such as high tree coverage (47,50,80) and terrain variability (60), were associated with more severe psychopathology. In both cases, these greenspaces may be inaccessible for people with mobility difficulties (60) and, consequently, reduce opportunities for behavioral or affective change following exposure. In other words, inaccessible greenspaces may not confer the same benefits as accessible ones. Although speculative, prevalent but inaccessible greenspaces may negatively affect qualitative experience of greenspace if perceived to be difficult to traverse or expensive to access. Negative qualitative experience of these greenspaces may translate into other domains of psychological functioning such as decreased self-efficacy or fewer opportunities for social connection. Greenspace access remains an understudied yet critical area of further study in its relationship to psychopathology.

While research methods varied and experimental work on addressing mechanisms is limited, greenspace exposure appears to be related to reduced severity and prevalence of psychopathology in children and adults. However, more research is necessary to clarify cognitive, affective, and behavioral mechanisms, as well as their interactions with urban features, that may contribute to psychological benefits of greenspace for those living with mental health concerns. It is probable that the benefits of greenspace are conferred by a combination of all of the above; the opportunities for physically engaging in greenspaces, away from negative urban environmental features, affects how we think and feel, which in turn influences how we engage with greenspaces. It remains unclear whether specific disorders are more sensitive to greenspace exposure or whether certain features of greenspace (e.g., accessibility) are particularly potent in delivering these effects. Optimally, future research would include both subjective and objective measures, in longitudinal and experimental designs, on a broader range of diagnoses and demographic characteristics, to help us further understand the relationship between greenspace exposure and potential psychological benefits.

ACKNOWLEDGMENTS AND DISCLOSURES

The authors report no biomedical financial interests or potential conflicts of interest.

ARTICLE INFORMATION

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Received Oct 15, 2021; revised Dec 15, 2021; accepted Jan 16, 2022.

Supplementary material cited in this article is available online at https://doi.org/10.1016/j.bpsgos.2022.01.004.

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